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Diporiphora reginae from Moonaree Station, South Australia (Photo: P. Tremul). See article on p. 53 for records of this species from South Australia.

Scrub python, *Morelia kinghorni*, from Bartle Frere, Queensland, incubating eggs (Photo: B. James). See article on p. 2 for a description of the nest.

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A RECORD OF OVIPOSITION SITE, CLUTCH SIZE AND HATCHLING SIZE FOR A FREE RANGING SCRUB PYTHON *MORELIA KINGHORNI* (SERPENTES: PYTHONIDAE) IN NORTH QUEENSLAND

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INTRODUCTION

The scrub python *Morelia kinghorni* (Stull, 1933) = *M. amethistina* in earlier literature, is Australia's largest snake, occurring primarily in rainforest and humid riparian and sheltered gully habitats in tropical eastern Queensland from Ayr to the Cape York Peninsula (Fearn & Trembath, 2006). In spite of being one of the largest snakes in the world, almost no quantified data existed for *M. kinghorni* until relatively recent times (Shine & Slip, 1990; Fearn *et al.*, 2005) and many aspects of its ecology remain poorly understood. The reproductive biology of this snake in the wild, in particular, is almost entirely unknown. Aggregations of adults are known to occur in exposed rocky slopes and gorges in the dry season (June to August) where intraspecific male combat and mating take place (Fearn *et al.*, 2005; Lloyd & Fearn, 2005). The bulk of published information on the reproductive biology of *M. kinghorni* originates from captive specimens (extensive data summarised by Ross & Marzec, 1990; Barker & Barker, 1994; Greer, 1997; Barnett, 2007). Pope (1961) provides the only record of a female *M. kinghorni* on a clutch of eggs in the wild and states "When encountered, a female amethystine python of Australia was coiled around 19 eggs in a hollowed out section of a staghorn at the base of a tree." Shine and Slip (1990) only discovered two adult females, both gravid (clutch sizes of 11 and 12), among Australian museum collections. The clutch size of captive Australian *M. kinghorni* ranges from 5-17 eggs with a mean of 10.4 (extensive data summarised by Greer, 1997), however clutch sizes from captive snakes can be highly misleading. Shine *et al.* (1999) found that average clutch sizes of wild reticulated pythons (*Python reticulatus*) were half that of published accounts from previous authors based on large, well fed captives.

OVIPOSITION SITE AND CLUTCH SIZE

On 5 February 2008 one of us (BJ) was requested to relocate a female *M. kinghorni* (snout-vent length (SVL) 2224 mm, mass 1820 g) coiled around nine eggs in a shallow depression (Figure 1) in debris piled up in a banana plantation (17°26.815'S 145°51.970'E) at Bartle Frere, north Queensland. The oviposition site was partially under the cover of regrowth vegetation on the edge of the debris pile beside a sugar cane field (Figure 2). The depression appeared to have been enhanced and 'shaped' by the female python in the substrate that consisted of soil, rotting wood fragments and pieces of dead palm fronds. After data collection the female was released in a nearby fauna reserve at Woopen Creek and the nine eggs collected and individually numbered with a pencil for artificial incubation. Mean egg size was 76.2 x 45.6 mm and mean mass 90.6 g (Table 1).

INCUBATION AND HATCHLING SIZE

The eggs were placed in a large plastic container on a mixture of 250 g of vermiculite soaked in 250 ml of warm water. A lid was placed on the container before being deposited in an incubator. The eggs were incubated at a constant 30°C and 80% humidity. On 14.ii.2008 slits appeared in two eggs indicating imminent neonate emergence and by the afternoon of the 16.ii.2008 all neonates had emerged (Figure 3). Each neonate was then

Table 1. Size (mm) and mass (g) of a clutch of eggs from a free ranging *M. kinghorni* from Bartle Frere, north Queensland.

Egg number	Size (mm)	Mass (g)
1	79 x 44	86
2	79 x 42	92
3	76 x 45	98
4	80 x 46	94
5	72 x 48	90
6	82 x 46	100
7	72 x 48	88
8	74 x 44	84
9	72 x 48	84

Table 2. Length (mm) and mass (g) of neonate *M. kinghorni* from Bartle Frere, north Queensland.

Neonate number	SVL (mm)	Mass (g)
1	550	110
2	550	102
3	548	112
4	555	108
5	550	100
6	557	102
7	546	90
8	553	95
9	558	108

measured (snout-vent length) and weighed before being released at a fauna reserve at Woopen Creek. Mean neonate length was 551.8 mm and mean mass 103 g (Table 2).

DISCUSSION

It may at first seem remarkable that this brief work is only the second published record of a female oviposition site and clutch size for a free ranging *M. kinghorni*, especially as the species is very large, locally common and well established in and around coastal towns and cities (eg. Cairns) throughout tropical coastal Queensland (Fearn *et al.*, 2005; B. James & S. Fearn, unpublished data). Several factors are probably responsible: a) this species has cryptic colouration; b) females may typically select well concealed nesting sites amongst dense vegetation, hollow logs etc (Slip & Shine, 1988a,b; Shine & Fitzgerald, 1996; Fearn *et al.*, 2001); c) the habitat of this species (tropical north Queensland) was largely isolated from professional university and museum zoologists until relatively recent times.

Figure 1. A female free ranging *M. kinghorni* on a clutch of nine eggs in a shallow depression on a pile of soil, rotting wood and dead palm fronds. Bartle Frere, north Queensland. Photo: B. James.

Figure 2. Pink rag in middle ground (arrowed) showing location of *M. kinghorni* nesting site in pile of debris with rainforest regrowth overstorey. Photo: B. James.

Figure 3. Neonate *M. kinghorni* shortly after emergence from eggs. Photo: B. James.

While the data presented in this work are limited, they agree in most respects with what little is known from previous captive studies. The mean egg dimensions and masses are similar to those from captive specimens; however the neonates in our sample were nearly twice as heavy as captive specimens (extensive data summarised by Barker & Barker, 1994; Greer, 1997). The timing of neonate hatching coincided with the collection of neonates in a field study between 2000 and 2003 at nearby Tully Gorge (Fearn *et al.*, 2005). Mean incubation period for captive *M. kinghorni* is three months and if similar incubation periods are typical for wild specimens, the time line between collection and neonate emergence for the female in this study appears to mirror field data collected to date (Fearn *et al.*, 2005) with mating taking place in the dry season (June-August), oviposition in the early wet season (November) and neonate emergence in February. Finally, the female in this work is the smallest sexually mature *M. kinghorni* recorded (Shine & Slip, 1990). Mark/recapture data from a large sample of field-caught *M. kinghorni* (Fearn *et al.*, 2005) suggested that females attain sexual maturity at 2270 mm (SVL) at two years of age, which indicates that our female may have reproduced for the first time.

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A SPECIALISED GENERALIST? NOTES ON THE DIET AND BEHAVIOUR OF THE MULGA SNAKE *PSEUDECHIS AUSTRALIS* (ELAPIDAE) IN THE KAMBALDA REGION OF WESTERN AUSTRALIA

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INTRODUCTION

This paper is based upon observations of the mulga or king brown snake *Pseudechis australis* made within a 50 km radius of the Kambalda East townsite, Western Australia (31°12'S 121°40'E), where I was resident from April 1981 until November 1994. I kept a record of all reptiles observed on a daily basis from 21 February 1986, but prior to this only observations I considered important were recorded. These earlier observations are not included in statistical summaries.

Mulga snakes were seen only infrequently, with sightings sometimes months apart, and were most often encountered incidentally, usually as 'roadkills'. Occasionally, live snakes were located and one was maintained in captivity (under licence by the then Department of Conservation and Land Management, Western Australia) for over five years.

Recent work by Kuch *et al.* (2005) suggests that several species may be present within *P. australis*. Mulga snakes from the Kambalda region correspond to the widespread clade II, both in terms of distribution and physical characteristics (large size, robust build).

OBSERVATIONS

During the period of daily observations (February 1986 to November 1994), 18 individuals were recorded (Table 1). Of these, 14 (78%) were dead when discovered, twelve of which (86%) were roadkills.

Coloration

Mulga snakes are typically described as being some shade of brown dorsally, with southern specimens tending to be darker to almost black (Gow, 1976; Smith, 1982; Mirtschin & Davis, 1983). Kambalda snakes were usually a dark olive colour, appearing quite greenish at times (Orange, 1992; Greer, 1997: 184, Fig. 7.46). One specimen, a roadkill from March 1989, was considerably darker than usual; the dorsal scales were pale olive brown at the base and very dark brown distally, giving an overall impression of a black-coloured snake.

Activity Patterns

Mulga snakes were only ever encountered active or, in the case of dead snakes, having been active; none were located under cover, or torpid during the colder months of the year. Snakes were recorded in most months in spring, summer and autumn, but not from winter months or early spring (Figure 1). A lack of activity in winter is not unexpected (most reptiles are inactive in these months at this latitude), although southern mulga snakes do appear to be cold tolerant (Mirtschin & Davis, 1983; Bush *et al.*, 2007). Two live snakes were encountered on cool but sunny days in May (one as late as 31 May) and a very recent roadkill was collected on 5 February 1992, a mostly cold, overcast day with intermittent showers (maximum temperature 24°C; Bureau of Meteorology records). I also received an anecdotal account of a mulga snake seen (basking?) early on a frosty morning in September (J. Godin, pers. comm.). Mulga snakes were found to be diurnal, becoming nocturnal in hot weather.

Size

Although the largest mulga snakes occur in the tropical north of Australia (Ehmann, 1992; Maryan, 1997; Bush *et al.*, 2007), Kambalda specimens attain sizes large enough to be mistaken for carpet pythons (*Morelia spilota imbricata*) by local townspeople on occasion (pers. obs.). The largest accurately measured mulga snake I recorded was

a roadkill of indeterminate sex, with a total length (TL) of 1510 mm and snout-vent length (SVL) of 1280 mm (Table 1). The average adult TL was 1319 mm and SVL 1123 mm. Adult males averaged larger than adult females, agreeing with the conclusions of Shine (1987). The smallest snake encountered was 360 mm TL and 310 mm SVL, and was regarded as a hatchling due to its obvious umbilical scar. The SVL of this snake exceeded hatchling sizes given by Shine (1987) and Bush (1995), but was within the range given by Fyfe (1991). Juvenile mulga snakes were noticeable by their absence. The only other small snake was a roadkill recorded in January 1984 (total length *ca* 600 mm). A perceived lack of juvenile snakes in wild populations is a recognised phenomenon (Shine, 1991a; Reinert, 1993), sometimes attributed to secretive behaviour as a means of predator avoidance.

Diet and feeding behaviour

Dead mulga snakes were usually examined for stomach contents, excepting extensively damaged roadkills or those in an advanced state of decay. The total number of specimens examined for stomach contents cannot be accurately ascertained; early records were sometimes left blank if a specimen was examined and did not contain prey items, while later records were marked "none apparent" in these circumstances.

Three snakes contained prey items (Table 1): two agamids, a typhlopid, and a mouse. Another road-killed mulga snake from Kambalda contained a gecko, *Underwoodisaurus milii*, and a skink, *Egernia formosa* (J. McGovern, pers. comm.). These records agree with the traditional view of mulga snakes as generalist predators consuming a range of vertebrate prey, with reptiles predominating (Shine, 1987). The disparity in size between predator and prey in the specimen containing the typhlopid was remarkable (TL = 1330 mm versus TL = 110 mm respectively), but consistent with the notion of *Pseudechis* species as opportunistic predators, unselective with respect to prey size and type (Shine, 1977, 1987, 1991b).

A captive mulga snake (wild-caught as an adult) was maintained for over five years on a diet of freshly killed or frozen and thawed mice (*Mus musculus*). Its prey-handling abilities on this diet could best be described as clumsy, especially in comparison to a pair of gwardars (*Pseudonaja nuchalis*) kept at the time. Although similar in length to the mulga snake (total length *ca* 1100 mm), the gwardars were much more slender in build and had smaller heads. Despite this, they were noticeably more adept at ingesting mice, taking and swallowing them within just a few minutes. The mulga snake however, would often spend many minutes manoeuvring a mouse in its attempts to swallow it. On occasion it would simply give up altogether and leave the mouse uneaten. Examination of these mice revealed them to be quite flattened in appearance, and observations of the mulga snake's feeding behaviour revealed why: they were being effectively chewed. This was causing the mouse carcase to become softened and malleable (enhanced perhaps by any venom injected) and therefore difficult for the snake to manipulate and swallow.

However, when the mulga snake was offered a fresh, road-killed yellow-faced whip snake (*Demansia psammophis*), a species common in the Kambalda region and a likely prey item of local mulga snakes (Shine, 1987, recorded *Demansia* spp. as prey items of mulga snakes), its behaviour changed, and it took the whip snake (an average-sized adult with TL *ca* 700 mm) eagerly. It rapidly ingested the whip snake, 'hauling' it down its throat with alternate movements of its lower jaw. The reaction to the whip snake and the adept manner by which it was consumed suggest that snakes might be a favoured prey of mulga snakes in the Kambalda region.

Gwardars (*Pseudonaja nuchalis*) are one of the more common snakes in the Kambalda region (pers. obs.) and mulga snakes are known to include gwardars in their diet (Shine, 1987; Nicolson & Mirtschin, 1995). Although I never recorded such an event, an incident did occur that suggested that gwardars may recognise the threat posed by

Table 1. Mulga snakes (*Pseudechis australis*) encountered in the Kambalda region, Western Australia during the period 21 February 1986 to 6 November 1994.

Date	Sex	Condition	Total Length (mm)	Snout-Vent Length (mm)	Stomach Contents	Comments
4.iv.1987	F	Roadkill	943	804	-	Midbody scale rows = 15 & 16
22.iv.1987	F	Killed by direct human action	1360	1165	*Ctenophorus reticulatus* (2); plus further agamid remains in lower gut	C. *reticulatus* (M): TL = 180 mm, SVL = 80 mm C. *reticulatus* (F): TL = 150 mm, SVL = 70 mm
26.iv.1987	-	Roadkill	-	-	-	Adult
31.v.1987	F	Active	1230	1050	-	Length measurements at post mortem, 5.x.1992
23.i.1989	-	Active	-	-	-	Adult
17.iii.1989	-	Roadkill	1320	1120	-	'Black' specimen; considerably damaged and in an advanced state of decay
26.iii.1989	M	Killed by domestic cat	360	310	None apparent	Hatchling; umbilical scar still obvious
15.x.1989	-	Active	-	-	-	Approx. TL = 1500 mm

Date	Sex	Condition	Total Length (mm)	Snout-Vent Length (mm)	Stomach Contents	Comments
16.iv.1990	F	Roadkill	1260	1085	*Mus musculus*	-
7.xi.1990	-	Roadkill	1510	1280	None apparent	Gut contained heavy parasite burden (roundworms)
5.v.1991	-	Basking	-	-	-	Adult
19.x.1991	-	Roadkill	-	-	-	Adult. Extensively damaged
19.x.1991	M	Roadkill	1330	1120	*Ramphotyphlops* sp.; small twig (40 mm)	*Ramphotyphlops* sp., TL = 110 mm
27.x.1991	-	Roadkill	-	-	-	Adult
5.ii.1992	M	Roadkill	1495	1285	None apparent	-
14.ii.1992	-	Roadkill	-	-	-	Extensively damaged. Approx. TL = 1000 mm
16.xi.1992	M?	Roadkill	1420	1200	None apparent	-
21.xi.1993	-	Roadkill	-	-	-	Considerably damaged. Approx. TL = 1200 mm

mulga snakes. A long-term captive gwardar of quiet disposition and the captive mulga snake were temporarily placed in separate cloth bags in a cardboard box, separated by a cardboard partition, for the purposes of transport to an educational display. The gwardar became agitated while in the bag, and vigorously attempted to escape when the bag was opened during the display. The mulga snake remained quiet throughout the entire period.

DISCUSSION

The serendipitous nature of mulga snake encounters may illustrate apparent abundance. Some species of reptile are common and easily located, whereas others seem rare until their habits or habitats are known (Shine, 1991a; pers. obs.). That is, some reptiles may appear common or rare depending upon a person's experience of them, irrespective of their actual abundance. However, mulga snakes seemed consistently uncommon in the Kambalda region throughout my time there. They did not appear to have specific habitat preferences other than my perception that they were encountered in the vicinity of (dry) creeks rather more than in other locations. Bedford (1991) likewise comments on the comparative rarity of the mulga snake in the Top End, but attributes this to its inefficiency as a hunter when compared to other snakes. Alternatively, their relative rarity may reflect their status as a top predator (Kuch *et al.*, 2005).

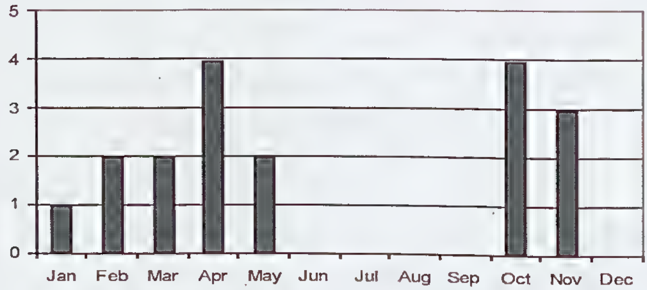
Another possibility may be that of 'cycles of abundance', natural long-term fluctuations in populations (Pianka, 1986; Beebee & Griffiths, 2000). The duration of a cycle may be such that it goes unnoticed unless an observer is resident in an area long enough to detect it. Although I lived in the Kambalda region for over thirteen years, mulga snakes remained scarce throughout this time whereas gwardars were common; during the period of daily observations, I encountered more than double the number of gwardars (39) compared to mulgas (18). However, almost a decade later (2002) mulga snakes were the more commonly encountered of the two species (B. Budrey, pers. comm.). The reason for this apparent shift in abundance is unknown.

Although mulga snakes are traditionally seen as generalist predators consuming a range of vertebrate prey (Gow, 1976; Kuch *et. al.*, 2005; Bush *et al.*, 2007), with reptiles predominating (Shine, 1987), in the most comprehensive dietary analysis to date (Shine, 1987), the most frequently eaten mammal was the introduced European house mouse *Mus musculus*. It has been posited that house mice have compensated for the loss of native mammals in the diet of southern mulga snakes (Maryan, 1997), but perhaps southern mulga snakes fed primarily on reptiles and simply included house mice as they became available.

Mulga snakes seem particularly well-adapted to preying upon reptiles. They are notorious for 'hanging on' and chewing when they bite, both when subduing prey and in self-defence (Kinghorn, 1964; Mirtschin & Davis, 1983; Sutherland, 1983), allowing them to inject copious amounts of venom, for which they are also renowned (Mirtschin & Davis, 1983; Sutherland, 1983). Such behaviour may be an adaptation for preying upon reptiles. Ectothermic prey are often slow to succumb to venom (Shine, 1985), and a counter to this may be the injection of large quantities of venom, and the retention of prey until they succumb. Further, mulga snake venom has a "devastating effect on other venomous snakes" (Mirtschin & Davis, 1983: 128), and the powerful jaws and chewing bite may help to penetrate the tough skin/scales of some reptiles (e.g., skinks), facilitating venom delivery. Indeed, mulga snake fangs are well suited for this purpose, as they are robust and relatively straight, whereas most other Australian elapids have fine curved fangs (Cogger... Covacevich, 1988). It is also possible that the sheer crushing force of the bite (pers. obs.) may play a role in killing prey, as in other ophiophagous snakes (Mushinsky, 1987).

Adult mulga snakes also feel 'hard-bodied' when handled (pers. obs.), having an overall rigidity about them, like skinks of the genus *Tiliqua*, and unlike the 'soft' bodies of many

Figure 1. Total number of mulga snakes (*Pseudechis australis*) encountered in the Kambalda region, Western Australia during the period 21 February 1986 to 6 November 1994.



other elapids. Such an adaptation may help to protect them from retaliatory bites and scratches inflicted by reptilian prey that is slow to succumb to the venom as the mulga snake hangs on. This could explain the number of scars seen on mulga snakes, particularly larger animals (pers. obs.).

Southern mulga snakes seem to be remarkably cold tolerant (Mirtschin & Davis, 1983; Bush *et al.*, 2007; pers. obs.). Cold tolerance would be an obvious advantage for a snake specialising in eating other reptiles, preying upon them while they are largely incapacitated by cold. Certain other elapids that feed on reptiles are similarly cold tolerant, for example, *Parasuta nigriceps* (Bush, 1981) and *Suta fasciata* (pers. obs.). Interestingly, like such small elapids, mulga snakes are also somewhat unsophisticated in their approach to prey subjugation: simply bite, hang on and pump in the venom. Ectothermic prey debilitated by cold may have a reduced ability to retaliate, rendering a more sophisticated method of subjugation (e.g., constriction) unnecessary. In contrast, gwardars, which include reptiles in their diets, constrict as well as envenomate their prey (Mirtschin & Davis, 1983; pers. obs.). However, as they tend to be active at higher temperatures than mulga snakes (Mirtschin & Davis, 1983; pers. obs.), their prey is more able to retaliate. They also include a greater proportion of mammals in their diet (Shine, 1991a), which, being endothermic, can retaliate effectively regardless of temperature.

Many of the larger Australian elapids feed on reptiles when young and extend their diet to include birds and mammals as they mature and/or grow large enough (Shine, 1991a; Greer, 1997). Whilst mulga snakes are obviously capable of preying upon a variety of vertebrates, aspects of their behaviour outlined here seem to indicate a degree of specialisation for preying on reptiles. Rather than being viewed as somewhat clumsy generalists, perhaps mulga snakes should be seen as efficient reptile specialists – after all, considering the size they can attain, they must be doing something right.

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CAPTIVE MANAGEMENT AND REPRODUCTION OF THE BROAD-HEADED SNAKE, *HOPLOCEPHALUS BUNGAROIDES* (SERPENTES: ELAPIDAE), A THREATENED AUSTRALIAN SNAKE, AT MELBOURNE ZOO

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ABSTRACT

The Broad-headed Snake (*Hoplocephalus bungaroides*) is a small elapid species restricted to a specific habitat of weathered, sandstone outcrops on the coast and ranges of south-eastern Australia. Broad-headed snakes are viviparous, with only a few instances of captive breeding recorded. The Melbourne Zoo breedings may represent the first such record for this species in a zoo.

INTRODUCTION

The Broad-headed Snake (*Hoplocephalus bungaroides*) is one of three species in the genus *Hoplocephalus;* all of which are confined to eastern continental Australia. (Cogger, 2000; Wilson & Swan, 2003). All three species are small snakes, with average adult lengths of about 60 cm. They are venomous and all are regarded as potentially dangerous, with an unsubstantiated human fatality recorded for *H. bungaroides* (Shine & Fitzgerald, 1989).

While *H. stephensii* and *H. bitorquatus* are wide ranging in their habitats and occur in rainforest to dry eucalypt forest respectively (Cogger, 2000; Fitzgerald *et al.*, 2005), *H. bungaroides* is restricted to crevices within exfoliating sandstone in the Sydney region of New South Wales. This habitat is also occupied by their main prey item, Lesueur's Velvet Gecko (*Oedura lesueurii*). Both *H. bungaroides* and *O. lesueurii* prefer exfoliating rocks of a particular thickness lying on other rocks, rather than rocks lying on soil (Shine & Fitzgerald, 1989).

However, while *H. bungaroides* occupies sandstone outcrops and uses rocks and crevices on exposed cliff edges as diurnal retreat sites, adult snakes undergo a seasonal habitat shift and venture into adjacent woodlands during late spring and summer to spend long periods in tree hollows (Webb & Shine, 1997; Worrell, 1963). The adult diet also changes during this time, with most meals comprising small mammals, rather than reptilian prey.

Small numbers of Broad-headed Snakes have been maintained in captivity by professional and amateur herpetologists in Australia for many years, but little information on their captive management, especially reproduction, is recorded.

Natural food items are recorded as lizards and frogs (Cogger, 2000). In captivity, adult snakes have eaten freshly killed laboratory mice and young rats, while freshly killed "day old" mice have been consumed by juvenile snakes (Shine & Fitzgerald, 1989).

With only a small amount of information available on the captive management and breeding biology of this species, and so few specimens in captivity, a proposal to obtain wild specimens and support the species' conservation was developed by the Australian Reptile Taxon Advisory Group (TAG) in 1993.

CONSERVATION STATUS

In the 1860s, *H. bungaroides* was common along the New South Wales central coast (Krefft, 1869). Its entire range falls within a 200 km radius of Sydney and it was included in The Action Plan for Australian Reptiles (Cogger *et al.*, 1993). The species is listed as vulnerable by the IUCN (IUCN, 2006) and the EPBC Act, primarily due to habitat

destruction over its restricted range and close proximity to an area of high human population (DEH, 2005; Newell & Goldingay, 2005). Unregulated collection of snakes and the rocks under which they shelter have been identified as the main threats to the species (Newell & Goldingay, 2005; Shine *et al.*, 1998; Webb *et al.*, 2002). Conservation measures have consisted mostly of field research, attempts to increase public awareness of the species plight and to protect areas of suitable habitat, particularly by discouraging the collection of sandstone slabs for landscaping.

The species threatened status was a major factor in the decision by the Reptile Taxon Advisory Group (TAG) of the Australasian Regional Association of Zoological Parks & Aquaria, Inc. (ARAZPA) to include *H. bungaroides* as a priority managed species in its 1999 TAG Action Plan (Banks, 1999; Porter *et al.*, 1998). The TAG was also of the view that captive maintenance and breeding by several institutions would enhance the collection of data on numerous aspects of the species natural history, including behaviour, diet, growth and longevity. Considering their high patronage, zoos and wildlife parks were also considered as an ideal vehicle for raising community awareness of, and support for the species' conservation. This was discussed with appropriate field scientists in developing the proposal to collect wild specimens.

MATERIALS AND METHODS

Sourcing snakes

A Species Management Plan was established under the auspices of ARAZPA's Australasian Species Management Program (ASMP), with a TAG proposal for the wild collection of eight snakes from the Newnes area close to Lithgow in the Blue Mountains, west of Sydney. The TAG proposal was lodged with the NSW National Parks & Wildlife Service (NPWS) by Taronga Zoo in 1994. Taronga Zoo subsequently obtained eight wild-caught snakes from the Newnes area between December 1994 and October 1997 (two of these were collected by researchers from the University of Sydney). A further three snakes of unknown provenance were lodged at Taronga Zoo by the NPWS in July 1995, and five more snakes were obtained from a private keeper in February 1998.

Eight snakes were retained at Taronga Zoo and the rest transferred to other zoos:

one male and one female (1.1) wild-caught specimens to the Australian Reptile Park in August 1996; 1.3 of the privately-sourced specimens to Melbourne Zoo in March 1999, and 1.1 of the specimens lodged by the NPWS to Healesville Sanctuary in July 1999.

Husbandry

On arrival at Melbourne Zoo the sexes of the four snakes were confirmed by cloacal probing. Each snake was issued a house number (females #1, 2 and 3; and male #4) and implanted with a transponder for permanent identification.

Each snake was initially housed indoors, separately in wooden enclosures measuring 600 mm x 435 mm x 400 mm, with glass front-opening doors. A mixture of silica sand and palm peat was used as a substrate and a small hide box provided. Temperatures were maintained from 23-31°C over summer and about 5°C cooler during winter.

Freshly killed, young fully furred mice were offered at approximately ten-day intervals, from September to March. All specimens settled in and fed well.

Specimen # 3 was placed on public display in a naturalistic enclosure (120 cm x 90 cm x 90 cm high), landscaped with sandstone.

Newborn snakes were housed two to a plastic terrarium, each measuring 340 mm x 200 mm x 140 mm, and kept on paper towel, with some sphagnum moss and a small plastic water dish.

Adult snakes were also held in two types of outdoor enclosures, the first constructed of recycled plastic and measuring 1200 mm x 740 mm x 740 mm, landscaped with river

sand substrate and rocks arranged to provide crevice retreats, and located in direct sunlight facing north-west with no supplementary heating. Temperatures were monitored, ranged from 9-32°C over a 24-hour period. With seasonal variation temperatures dropped below 9°C in mid winter and rose above 32°C in mid summer.

The second type of enclosures were glass-fronted wooden enclosures measuring 600 mm x 435 mm x 400 mm. These were protected from bad weather by plastic roofing above the enclosure tops, and fitted with two blue 25W light globes for supplementary heating.

Reproduction

The male was rotated through all the female's enclosures during the 1999 spring and summer beginning on September 16. No matings were observed, but female #1 gave birth to nine live young on 22 February 2000. One neonate died shortly after birth and the surviving eight snakes were housed in plastic terrariums.

After their first slough on 28 February, the snakes were offered newborn pink mice. As these were continuously refused, force-feeding hind legs of fuzzy mice was commenced. The snakes were fed this way approximately every five days until 10 April, when the food size was increased to a force-fed half pinky mouse. This was increased to a full-sized pinky mouse on 2 November and by 1 December all snakes were eating without assistance.

Female # 3 produced one slug (unfertilized ovum) on 7 March 2000 and passed a fully formed stillborn neonate on 10 March. An x-ray revealed a further five slugs still in the oviduct and oxytocin was administered once daily for three days in an attempt to induce the snake to pass them. The oxytocin failed to produce the desired results and Melbourne Zoo veterinarians surgically removed the five slugs, without apparent damage to the oviduct, on 14 March.

In spring 2000 the four adult snakes continued to be housed indoors, with the male being rotated through the females' enclosures. Female #3 produced three live young on 22 February 2001.

On 5 April 2001, female # 2 and the male were moved to adjoining outdoor enclosures without supplementary heating.

On 12 April, the female was observed with a section of her body extended from the crevice in full sunlight. The temperature of the rock was 21°C. Both snakes were using rock crevices as overnight retreats in early May. The female sloughed at 1045hrs on 7 May and was sunning herself on the enclosure floor, where the temperature was 14°C. She was observed moving around the enclosure and was placed into the male's enclosure at 1200hrs, along with her freshly sloughed skin.

Male courtship behavior (body tremors) was observed at 1300hrs and a small amount of faecal material deposited on a rock. The snakes continuously copulated from 1300hrs to 1540hrs. The next day, both snakes were observed stretched out and not displaying any mating behavior. This was a sunny day, with the enclosure substrate at 18°C and basking rock at 32°C. The female was again observed sunning on 4 June, with a rock surface temperature of 27°C.

Both specimens were allowed to brumate together in rock crevices and were observed sunning together on 30 July on rock ledges, where the surface temperature was 27°C. The male was separated from the female on 14 August and placed in the adjoining enclosure.

Both snakes were rotated on a "minimal disturbance" basis, as the rock crevice retreats made it difficult to move a particular specimen at a specified time. Female #2 produced six live young and two "slugs" on 16 February 2002.

Due to the difficulties involved in servicing the large outside "rock retreat" enclosures, male #4, female # 1 and female # 2 were moved

Table 1. Summary of reproductive events for *H. bungaroides* at Melbourne Zoo.

Female ID	Birth Date	Birth Event
#1	22 February 2000	9 live neonates (Breeding #1)
#3	7 March 2000 14 March 2000	1 slug Surgically removed 5 slugs
#3	22 February 2001	3 live neonates (Breeding #2)
#2	18 March 2001	8 slugs
#2	16 February 2002	6 live neonates and 2 slugs (Breeding #3)
#1	18 May 2003	2 still born neonates (Breeding #4)

to the smaller glass-fronted outdoor enclosures on 17 June 2002.

Male #4 was observed mating with female # 1 on 12th September 2002 in these outside wooden enclosures, resulting in two stillborn neonates on 18 May 2003.

The birth events from 2000 to 2003 are summarised in Table 1, and the average birth weight and snout-vent length in Table 2. Most young snakes grew well (Table 2) and were easily maintained. Five of the 18 snakes born alive died within 24 months – four from breeding #1 (one at two weeks of age, one at 12 months, one at 15 months and one at 24 months) and one from breeding # 3 at one month. Four of the young snakes were transferred to other zoos – two from breeding #1, at 24 months of age and two from breeding #3 at 12 months of age. Attempts to sex the young snakes produced a sex ratio of two males and 12 females, with seven unsexed.

DISCUSSION

It was decided that no attempt to provide a natural diet (i.e. geckos and skinks) would be made due to the complexities of state faunal protection laws and zoo ethics committee which prohibit using any native species as food and the possibility of introducing parasites.

The rotating of specimens was for the purpose of encouraging the male to become re-interested in sexual activity.

The litter sizes recorded at Melbourne Zoo are within the range (4-12) previously reported for *H. bungaroides* (Shine & Fitzgerald, 1989; Worrell, 1963). Shine and Fitzgerald (1989) have also reported a high proportion of stillborn offspring from captive snakes held by Fitzgerald. It also accords with litter sizes of 3-6 in captive *H. bitorquatus* (Lazell, 2000).

It is possible that the first birth of nine neonates (being the largest litter we recorded) was the result of a wild mating. The second highest, of six neonates and two slugs, arose from a captive mating and were produced by snakes kept outdoors in an environment with highly variable temperatures, but generally comparable (though cooler overall) to temperatures found in their natural habitat. Summer daily maximums were generally between 25-28°C, but on occasions reached 32-35°C. The smaller litter sizes were produced by snakes kept in more constant indoor, "temperature controlled" conditions.

Table 2. Average birth weights, lengths, and growth rates for captive bred *H. bungaroides* at Melbourne Zoo.

	Mass (grams)	Snout-vent (mm)	Total length (mm)	N
Breeding # 1				
Birth	5.08	190	234	9
3 months	5.74	242	276	8
20 months	30.58	400	428	6
24 months	64.58	495	571	3
Breeding # 2				
Birth	5.63	211	249	3
12 months	8.49	306	356	3
Breeding # 3				
Birth	4.15	203	233	6
1 month	5.32	228	253	6
7 months	7.72	284	310	5
15 months	27.50	432	497	3
Breeding #4				
Birth	3.56	187	218	2

Though more work is required, these findings may reflect the general trend in many snakes from temperate Australia, in which males require exposure to low winter temperatures for spermiogenesis and, hence, subsequent successful mating (Shine, 1991).

The high level of stillbirths encountered with *H. bungaroides* at Melbourne Zoo constitutes an issue that needs to be resolved. A number of factors have been suggested as underlying causes for stillbirths in wild snakes. Kissner *et al.* (2005) found more stillbirths in multiple-sired offspring of Northern Watersnakes (*Nerodia sipedon*), whilst Madsen *et al.* (1992) found the reverse in a wild population of European Adders (*Vipera berus*), i.e. that multiple matings significantly reduced the proportion of stillbirths.

Another factor that has been shown to affect offspring survival is the temperature to which the female is exposed during pregnancy. In a study of the effect of developmental temperature on embryo mortality in the Garter Snake (*Thamnophis elegans*), embryo survival was highest at an intermediate temperature of 26.6°C (O'Donnell & Arnold, 2005). Increasing rates of stillbirths resulted from developmental temperatures of 21°C and 29-32°C. Temperature also had a significant effect on the sex ratio of stillborn young; with male mortality minimized at intermediate and higher temperatures. Loss of genetic variation

can also result in a high percentage of still-births or deformities, which have been recorded in isolated populations of the Hungarian Meadow Viper (*Vipera ursinii rakosiensis*). Indeed, a small total population having low genetic diversity is currently considered the prime threat to the subspecies (Ujvari *et al*., 2002). In view of the nature of the habitat where *H. bungaroides* occurs, in particular the isolated rocky outcrops, compounded by increasing fragmentation, it is possible that *H. bungaroides* is facing loss of genetic variation.

Captive-bred specimens were provided to other zoos to supplement their holdings and support the establishment of public displays and additional captive breeding groups as part of the regional plan for the species. However, Melbourne Zoo seems to have had most success in maintaining and breeding this species to date.

Apart from continuing to develop successful strategies for captive management of Broad-headed Snakes, Melbourne Zoo will maintain an ongoing naturalistic public display to help highlight the plight of this threatened species.

Recommendations for captive breeding

Provide snakes with seasonal and daily temperature variation similar to what they would experience in their natural environment with an emphasis on winter minimum temperatures.

Explore the effect of developmental temperature and whether it may explain, at least in part, the high rates of still-birth encountered in *H. bungaroides* at Melbourne Zoo, as the largest number of surviving young is correlated with caging which provided the adult snakes access to a daily thermal temperature range in which they could choose their preferred temperature(s). It is also a factor that could be explored further, to determine if it is an important parameter and, if so, the preferred developmental temperatures of gravid females.

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GASTRIC NEMATODES OF SNAKES AND LIZARDS FROM THE VICTORIAN MALLEE

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INTRODUCTION

The Victorian Mallee covers a vast semi-arid plain of mild winters and hot dry summers, with little seasonal variation in the low rainfall. The predominant vegetation consists of low multi-stemmed *Eucalyptus* species, with communities of heath, *Triodia* grassland and saltbush plains (Swan & Watharow, 2005). The present distribution of Mallee is broken into several separate distinct areas, the Sunset Country and the Big Desert Wilderness Park in the northwest of the State being the largest regions. The herpetofauna of this Mallee has been studied (Rawlinson, 1966; Coventry, 1996a,b; Swan & Watharow, 2005) and its composition demonstrates that the area forms a transition zone between the cooler, damper southeastern regions of Australia, the Bassian region, and the warmer and drier Eyrean region (Coventry, 1996b). The reptile fauna is rich and varied, and many species have an extensive distribution, especially in southern Australia. Little is known of the nematode parasites of this fauna; although studies have been undertaken on related species elsewhere in Australia, we are not aware of any studies on reptiles from this Mallee. This preliminary study was therefore undertaken to assess the species and prevalence of gastric nematodes in ten of the more common reptiles from this habitat, and to compare the findings with studies undertaken in the Great Victoria Desert (Jones, 1995a), and from the same or related reptile species from elsewhere in Australia.

METHODS

One hundred and sixty-five reptiles of ten species were examined from the collection in Museum Victoria, Melbourne. All had been collected from the Big Desert Wilderness and Sunset Country. They comprised four species of Agamidae (Norris' Dragon *Amphibolurus norrisi* n = 20, Painted Dragon *Ctenophorus pictus* n = 10, Mallee Dragon *C. fordi* n = 22, and Central Bearded Dragon *Pogona vitticeps* n = 20), one species of Pygopodidae (Southern Legless Lizard *Delma australis* n = 15), two species of Scincidae (Eastern Striped Skink *Ctenotus orientalis* n = 35, and Shrublands Morethia Skink *Morethia obscura* n = 18), and three species of Elapidae (Masters' Snake *Drysdalia mastersii*, n = 8, Bardick *Echiopsis curta* n = 2, and Mitchell's Short-Tailed Snake *Parasuta nigriceps* n = 15). Stomachs were opened under a dissecting microscope using a 10x objective, the contents removed and nematodes cleaned and stored in 70% ethanol. They were subsequently cleared in chlorolactophenol and examined using an Olympus BH microscope. All worms will be returned to Museum Victoria, Melbourne.

The following terms are used to express aspects of the worms' biology: *prevalence* refers to the number of reptiles infected with one or more individuals of a particular parasite, expressed as a percentage; *intensity* refers to the number of individuals of a particular parasite in a single infected host, usually expressed as a mean (Bush *et al.*, 1997). A *paratenic host* is a one in which the parasite remains viable but does not develop.

RESULTS

Nematode species recovered

Six species of nematode were recovered from nine of the ten reptile species (Table 1); no nematodes were recovered from *Ctenophorus fordi*. *Abbreviata antarctica*, *Kreisiella*

lesueurii, Pseudorictularia disparilis, Physalopteroides filicauda (Physalopteroidea), and *Maxvachonia brygooi* and *M. chabaudi* (Cosmocercidae) were identified.

Prevalence and intensity of infection were low; the overall prevalence of infection was 17.6%, ranging from 45% in *P. vitticeps* to nil in *C. fordi*. A majority of infections (21/29: 72%) was with <5 worms. *Abbreviata antarctica* was present at highest intensity (mean, 16.5 worms/per host, including larvae). In all six nematode species, females outnumbered males; male:female ratio was 2:3 in *A. antarctica*. Apart from a single male *K. lesueurii*, only females or immature worms were recovered from other species.

Concurrent infections

Twenty of the 29 infected reptiles were infected with a single species only. One *A. norrisi* was infected with three species (*A. antarctica, P. disparilis* and *M. brygooi*), two *P. vitticeps* were infected with *A. antarctica* and with *K. lesueurii* and *M. brygooi* respectively, and one *C. orientalis* was infected with *Kreisiella* sp. and with *Ph. filicauda*.

Encysted physalopterid larvae (presumed to be *Abbreviata* spp.)

Encysted larvae were seen in the stomach tissues of five *C. orientalis* (14%), in numbers between one and *ca* 50.

DISCUSSION

Mallee provides a large number of microhabitats which can be exploited by reptiles, thus reducing competition (Coventry, 1996a; Pianka, 1986), and the species examined in this study occupy different spatial and temporal habitats. The Central Bearded Dragon (*Pogona vitticeps*) and Norris' Dragon (*Amphibolurus norrisi*) are heliothermic and semi-arboreal, Painted Dragons (*Ctenophorus pictus*) are heliothermic and terrestrial, and Eastern Striped Skinks (*Ctenotus orientalis*) and Shrublands Morethia Skinks (*Morethia obscura*) are also terrestrial, living around grass tussocks, low dense shrubs and leaf litter. All these species are diurnal. The Southern Legless Lizard (*Delma australis*) is both diurnal and nocturnal, Masters' Snake (*Drysdalia mastersii*) is diurnal, and Mitchell's Short-Tailed Snake *Parasuta nigriceps* and the Bardick (*Echiopsis curta*) are nocturnal (Cogger, 2000; Coventry, 1996b; Robertson *et al.*, 1987; Swan & Watharow, 2005). Their habitat selections and differences in size and feeding techniques lead to consumption of different food and prey types; for instance, elapid snakes are almost exclusively vertebrate feeders, whereas arthropods are a more conspicuous element in the diet of lizards. These behavioural and ecological factors, together with the innate host specificity of the parasites, provide some explanation of the different parasite profile between hosts.

In the present study only stomachs were examined, and therefore the presence of nematode species which predominantly inhabit the intestines or rectum, such as *Maxvachonia* spp. (Inglis, 1968; Jones, unpublished) would have been under-reported. Nonetheless, these data are valuable in recording new host species for some nematodes, extending their known range, and providing evidence which supports earlier findings from a desert study and from related host species.

Abbreviata antarctica was described from the Western Blue-Tongued Skink (*Tiliqua occipitalis*) and the Common Death Adder (*Acanthophis antarctica*) in South Australia by von Linstow (1899), and is now known to be widespread in many of the larger species of reptiles in Australia, principally in less hot and less arid parts of the continent. It was recorded from the Eastern Bearded Dragon (*P. barbata*) in southern Mallee habitats (Little Desert National Park), (Watharow, 1998), and in Sydney (Johnston & Mawson, 1943), in two subspecies of *Pogona* (*P. minor minima* and *P. m. mitchelli*) in south-western Australia and in the Kimberley (Jones, 1986), and from 1/12 *E. curta*, also in south-western Australia (Jones, 1978). This is the first record of *A. antarctica* from *P. vitticeps*, and further evidence for its wide host range. In this reptile

population, *P. vitticeps* can be designated a 'core host'. The preponderance of females in this species, and in all other five nematode species in this study, is a frequent finding. Possible explanations may involve a shorter life-expectancy in males, and possibly in their usually being smaller than females, and hence more easily overlooked.

Only a single male *Kreisiella* sp., *K. lesueurii*, was recovered from *A. norrisi*; females of *K. lesueurii* and *K. chrysocampa* are difficult to differentiate except by size and the number of apical denticles, and it is possible that both species are present in this lizard population. *K. chrysocampa* attains highest prevalence in *Egernia inornata* and *Ctenophorus* species, usually at low intensity (mean 1-2.2; Jones, 1995a), as shown in hosts in this study, but in *P. m. mitchelli* in arid and semi-arid northern Western Australia *Kreisiella* sp. may attain an intensity of 20 worms per host (Jones, 1986). Smaller lizards form a significant element of the diet in the dragon lizards *A. norrisi* and *P. vitticeps*, and of the snake *D. mastersii* in this ecosystem (Coventry, 1996b), and infections of *Kreisiella* sp. in these reptiles may be due to their ingestion of infected skinks.

Physaloptera filicauda has been recorded from a wide range of lizard species, most commonly in the smaller species such as skinks and geckos (Jones, 1995a). *Pogona vitticeps* and *D. australis* are new host records for this species. *Pseudorictularia disparilis* is predominantly a parasite of amphibians (Irwin-Smith, 1922), and its sporadic occurrence in reptiles in this and other studies probably results from their ingesting an invertebrate host shared with frogs, three nocturnal species of which occur widely in this Mallee (family Myobatrachidae; Swan & Watharow, 2005). None were found in a very large number of lizards from the more arid Great Victoria Desert (Jones, 1995a). *Maxvachonia brygooi* was described from several species of agamid lizards, and *M. chabaudi* from seven species of skink (Mawson, 1972), predominantly from south-western or south-eastern Australia. Both have subsequently been identified from a number of other species – the Frillneck Lizard (*Chlamydosaurus kingii*) in tropical northern Australia (Jones, 1994), Heath Monitor *Varanus rosenbergi* in the south (Jones, 2005) and from a skink and a snake in Tasmania (Jones, 2003); none were found in the Great Victoria Desert (though intestines were not examined in that study; Jones, 1995a). Findings in the present survey thus complement these previous studies and indicate that this genus occurs predominantly or exclusively in the more humid southern Bassian region and the monsoonal Torresian region. Cosmocercid nematodes are direct-infection, though transmission of species of *Maxvachonia* has not yet been studied (Anderson, 2000), and the known distribution suggests that eggs (and/or free-living larvae) cannot survive excessive desiccation. The presence therefore of both these species supports the evidence that the Victorian Mallee is a transitional region.

The absence of male worms in *P. disparilis* and *Maxvachonia* spp. is not unexpected. Males of *P. disparilis* have recently been reported from lizards for the first time (Jones and Watharow 2010, in press), and males of *Maxvachonia* are considerably smaller than females, and are infrequently recovered.

Cysts containing physalopterid larvae are a common finding in a large number of smaller lizards, particularly skinks and geckos, and rarely occur in larger species which may harbor adult *Abbreviata* species (Jones, 1995a). This finding, and the almost complete absence of host inflammatory response to these larvae (Jones, 1995b) suggests that the lizards in which they occur are paratenic hosts. Their occurrence in the stomach walls of *C. orientalis*, and not in the larger species of agamid lizards in the present study, thus supports previous findings.

The absence of gastric nematode infections in *C. fordi* probably reflects their diet of ants (and possibly their short life-spans; Cogger, 1978). Gastric nematodes were found at very low prevalence in Military Dragons (*C. isolepis*) and Central Netted Dragons (*C. nuchalis*) in the desert (Jones, 1995a). In

Table 1. Adult nematodes recovered from ten species of reptiles from Victorian Mallee

	Nematodes: Prevalence; intensity in parentheses					
Reptiles	*A. antarctica*	*K. lesueurii*	*Ps. disparilis*	*Ph. filicauda*	*M. brygooi*	*M. chabaudi*
Amphibolurus norrisi (n =20)	1 (12)	1 (12)	1 (8)	-	1 (7)	-
Ctenophorus pictus (n = 10)	-	-	-	-	1 (1)	-
Ctenophorus fordi (n = 22)	-	-	-	-	-	-
Pogona vitticeps (n = 20)	6 (4-25; x:11)	2 (2)	-	1 (4)	1 (1)	-
Delma australis (n = 15)	-	-	-	2 (1.5)	-	-
Ctenotus orientalis (n = 35)	-	1 (1)	2 (2.5)	2 (2)	1 (5)	-
Morethia obscura (n = 18)	-	1 (2)	-	-	-	-
Drysdalia mastersii (n = 18)	-	1 (3)	-	-	-	-
Echiopsis curta (n = 2)	1 (2)	-	-	-	-	-
Parasuta nigriceps (n = 15)	-	-	-	-	2 (1.5)	1 (2)

these species ants form a high proportion of the diet (Pianka, 1986). This absence of nematode infection in *C. fordi*, and the absence of gastric nematodes in *C. pictus* (*M. brygooi*, recovered from one specimen, is typically an inhabitant of the lower gut and rectum) add further support to the observation that, as in Thorny Devils (*Moloch horridus*), ant-feeding lizards in arid Australia infrequently support gastric spirurid nematodes.

CONCLUSIONS

The findings in the present study support conclusions regarding nematode community structure in the Great Victoria Desert (Jones, 1995a): adult *Abbreviata* species occur in larger reptiles, and physalopterid larvae occur encysted in the tissues (mainly stomach and mesentery) in species of smaller lizards. These act as paratenic hosts in which no further development occurs unless they are consumed by a larger reptile species. *Physalopteroides filicauda* is found in a wide range of smaller lizards. *Maxvachonia* spp. and *Pseudorictularia disparilis* have not been recorded from desert areas, and on present information only occur in northern and southern areas of higher rainfall (Bassian and Torresian regions), although it should be noted that *Maxvachonia* live primarily in the lower intestine, which was not examined in this study. Their occurrence in this ecosystem supports the conclusions of Coventry (1996b) that the Victorian Mallee presents a transition zone between two major ecological zones. Both the prevalence and intensity of nematodes in all host species (except *Pogona vitticeps*) were low, and larger studies, to include more host species, could amplify these conclusions. Other aspects of the reptile ecology, such as density of individuals and species diversity, may also influence their nematode communities.

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APPENDIX. COLLECTION DATA OF INFECTED SPECIMENS

Agamidae

Amphibolurus norrisi:
D51521, 35 km S Nhill, 36°38.00'S 141°39.00'E (6.x.1978); **D59684,** 35°39.00'S 141°39.00'E (7.iv.1987).

Ctenophorus pictus:
D52998, 3.3 km NNW Chinaman Well, 35°51.27'S 141°38.57'E (9.xii.1979).

Pogona vitticeps:
D56290, 2.2 km NE Chinaman Well, 35°52.2'S 141°40.32'E (2.xi.1979); **D53907,** 2 km N Chinaman Well, 35°52.22'S 141°40.31'E (10.viii.1980); **D54557,** 2 km N Chinaman Well, 35°52.22'S 141°40.31'E (10.viii.1980); **D54754,** 5 km NNW Chinaman Well, 35°50.45'S 141°38.40'E (20.x.1980); **D54789,** 4.7 km ENE Chinaman Well, 35°51.42'S 141°42.05'E (22.x.1980);

D54790, 3 km NE Chinaman Well, 35°52.09'S 141°41.11'E (22.ix.1983); **D55036,** 5.5 km NNW Chinaman Well, 35°50.35'S 141°38.00'E (8.xii.1980); **D59644,** 20.3 km SE Murrayville, 35°24.00'S 141°20.00'E (25.ii.1987); **D54051,** 0.6 km NNE Chinaman Well, 35°53.42'S 141°39.49'E (23.iii.1980).

Pygopodidae

Delma australis:
D54814, 1.3 km N Chinaman Well, 35°52.44'S 141°38.05'E (23.x.1980); **D53943,** 3 km NE Chinaman Well, 35°52.09'S 141°41.11'E (21.ii.1980).

Scincidae

Ctenotus orientalis:
D52729, 5.1 km NNW Chinaman Well, 35°50.46'S 141°38.05'E (9.xii.1979); **D53507,** 3.3 km NNW Chinaman Well, 35°51.27'S 141°38.57'E (22.i.1980); **D54775,** 3.3 km NNW Chinaman Well, 35°51.27'S 141°38.57'E (22.x.1980); **D54924,** 2.05 km NNW Chinaman Well, 35°51.55'S 141°39.32'E (21.xi.1980); **D61020,** 19.2 km N Millewa South Bore, 34°37.00'S 141°04.00'E (13.xi.1985); **D61024,** 19.2 km SSW Murrayville, 35°26.00'S 141°10.00'E (13.xi.1985).

Morethia obscura:
D61079, 14.5 km NW Lascelles, 35°33.10'S 142°26.03'E (22.i.1987).

Elapidae

Drysdalia mastersii:
D59694, 16.8 km SSW Murrayville, 35°25.00'S 141°09.00'E (28.x.1985).

Echiopsis curta:
D59712, midway between Last Hope Tank and lower edge of Raak Plain (13.ii.1986).

Parasuta nigriceps:
D61270, 3.9 km N Hattah, 34°43.00'S 142°16.00'E (25.i.1987); **D61276,** 17.5 km NE Patchewollock, 35°15.00'S 142°19.00'E (28.i.1987); **D61281,** 16.8 km SSW Murrayville, 34°25.00'S 141°09.00'E (18.ii.1987).

SURVEY OF AMPHIBIANS IN THE DHARAWAL RESERVES ON THE SOUTH COAST OF NEW SOUTH WALES

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ABSTRACT

Herpetologists have visited the Dharawal reserves and freehold land in the Darkes Forest area for over forty years as it supports a high species diversity of amphibians. However, until recently there have been few systematic surveys of the frogs within the O'Hares Creek catchment. Ten 250 m transects located along perennial creeks were surveyed at night for 30 minutes each. Nocturnal searches were also conducted beside ephemeral ponds and dams and diurnal searches were conducted for tadpoles. A dam was also searched for 30 minutes. The current survey detected seventeen species of frog in the reserves including the Heath Frog *Litoria littlejohni*, Giant Burrowing Frog *Heleioporus australiacus* and the Red-crowned Toadlet *Pseudophryne australis*, which are currently listed on Part 2 of the Threatened Species Conservation Act (1995) as vulnerable. In addition the Dwarf Tree Frog *Litoria fallax* has been previously recorded from farm dams at Darkes Forest. The chytrid frog fungus was detected in populations of *Litoria littlejohni* (tadpoles), Blue Mountains Tree Frog *Litoria citropa*, Freycinet's Frog *Litoria freycineti*, Green Stream Frog *Litoria phyllochroa*, Common Eastern Froglet *Crinia signifera* and Pobblebonk *Limnodynastes dumerilii grayi*. No animals were observed to express symptoms of the disease. Other threatening agents detected include the presence of the Plague Minnow *Gambusia holbrooki* and the non-endemic Yabbie *Cherax destructor*.

INTRODUCTION

Although the Darkes Forest area (including the Dharawal reserves) had been regularly searched for amphibians since the 1970s (M. Anstis, pers. comm.) there have been few systematic stream-side searches that could provide a basis for monitoring. Harlow and Taylor (1995) surveyed the herpetofauna within the O'Hares Creek and spent 31 hours searching eight sites for amphibians. This included recognition of species by call, drive transects, the retention of tadpoles till metamorphosis and spotlight searches beside creeks. Harlow and Taylor (1995) detected fourteen species of frog during their survey including *P. australis* and *H. australiacus*. DECC (2007a) conducted 13 streamside searches that employed thirty minute searches along creeks. This survey represents the only systematic published data on the area's frog fauna.

The Dharawal State Conservation Area (DSCA) (6380 hectares) and Dharawal Nature Reserve (DNR) (377 hectares) (hereon referred to as 'the reserves') (Figure 1) support populations of the Heath Frog *Litoria littlejohni*, Giant Burrowing Frog *Heleioporus australiacus* and Red-crowned Toadlet *Pseudophryne australis*, species that are currently listed on Schedule 2 of the Threatened Species Conservation (TSC) Act (1995) as Vulnerable (NPWS wildlife atlas records). Historically the Green and Golden Bell Frog *Litoria aurea* was known from the area and the Stuttering Frog *Mixophyes balbus* has been recorded in the broader region.

Vehicular access is restricted in the Dharawal reserves to protect stream and swamp water quality and reduce vandalism. Most frog surveys in the region have been by way of road drive transects and inspections of farm dams in the Darkes Forest area beside Maddens Creek (J. Barker, pers. comm.; M. Anstis, pers. comm.; G. Daly, pers. obs.). The latter site had vehicular access until 1996 and currently it is still surveyed annually by members of the Frog and Tadpole Study Group (M. Anstis, pers. comm.), being a few hundred metres walk from the Darkes Forest Road.

The aim of the current survey was to undertake systematic surveys for amphibians in the reserves targeting threatened species. Swab samples from a variety of frog species were taken to test for the presence of chytrid fungus in the reserves and to provide an indication as to the extent of the disease. Searches were also conducted for the Plague Minnow *Gambusia holbrooki* and Yabbie *Cherax destructor* as they have been identified in the TSC Act (1995) and by Daly and Craven (2007) as species that threaten frogs. DECC (2007a) stated that the Stony Creek Frog *Litoria wilcoxii* and *Litoria nudidigitus* occur in the reserves and searches were conducted for these species. The Pobblebonk *Limnodynastes dumerilii* was also investigated to ascertain the subspecies form/s that occurred in the reserves.

METHODS

Description of study area

The Dharawal reserves (centred near 34°13'S 150°53'E) are located 13 kilometres south-east of the city of Campbelltown in the Illawarra Region of New South Wales near the village of Darkes Forest (Figure 1). The climate is mild (average range of 15 - 28°C in summer and 3 -19°C in winter) being moderated by the close proximity to the sea (Australian Government Bureau of Meteorology website). The average temperatures are influenced by the region's elevation being 200 - 380 m AHD. The Appin 1: 25000 topographic map indicates that the average annual rainfall for the region is 847 mm occurring fairly evenly throughout the year. Climate data from Campbelltown (Australian Government Bureau of Meteorology website) indicates the mean maximum rainfall is highest in summer and early autumn (79 - 101 mm) and lowest in late winter and early spring (34 - 50 mm).

Geology and soil

The area has a variety of rock formations and geomorphology (Hazelton *et al.*, 1990). The predominant geology is Hawkesbury Sandstone (from the Bundeena and Hawkesbury groupings). The Bundeena group has very low rolling rises. Small swamps and seepage areas are common on benches and along drainage lines. The Hawkesbury group has rugged rolling to very steep hills and rock outcrops are common. Ridges and narrow incised valleys, broken scarps and boulders are features of this landscape. There are also small areas derived from the Hawkesbury group (Madden Plains landscape). This landscape has moderate to gentle rises dominated by hanging swamps (dells). The soils derived from these landscapes have low soil fertility and consequently much of the original vegetation that exists in these areas has been retained.

Small occurrences of more fertile soils derived from the Mittagong Formation (alternating bands of shale and fine-grained sandstone) and Wianamatta Shale originally supported woodland, open forest and tall open forest (O'Hares Creek Shale Forest Community). These primarily occur within the Darkes Forest village, but the western edge of the reserves has a small occurrence of soil derived from Wianamatta shales.

Vegetation communities

The vegetation communities identified in the area are described by Keith (1994) and NPWS (2003). The vegetation is primarily woodland, open forest and tall open forest in the gullies. The most common vegetation community is exposed sandstone woodland

Figure 1. Location of Dharawal State Conservation Area and Nature Reserve

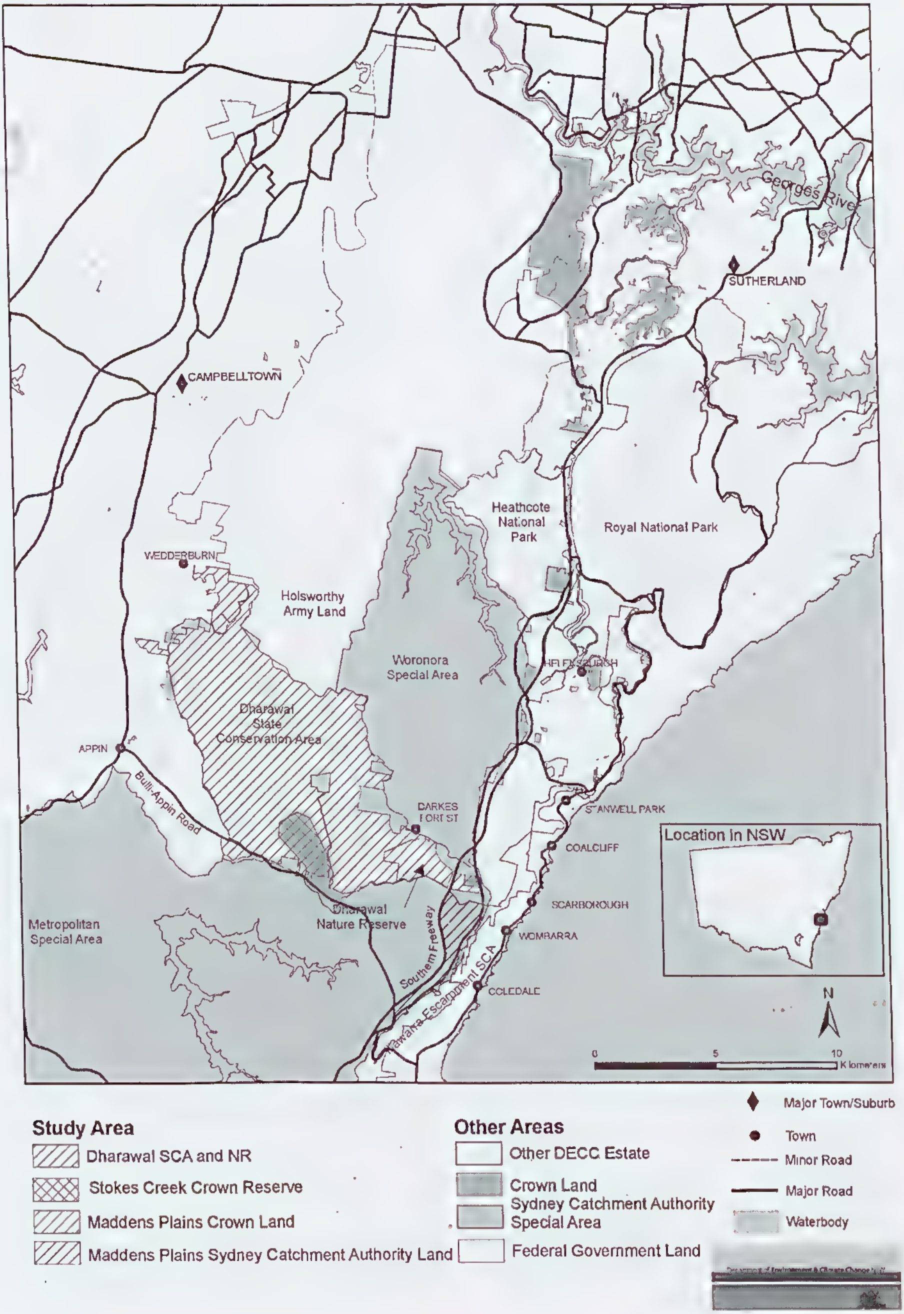
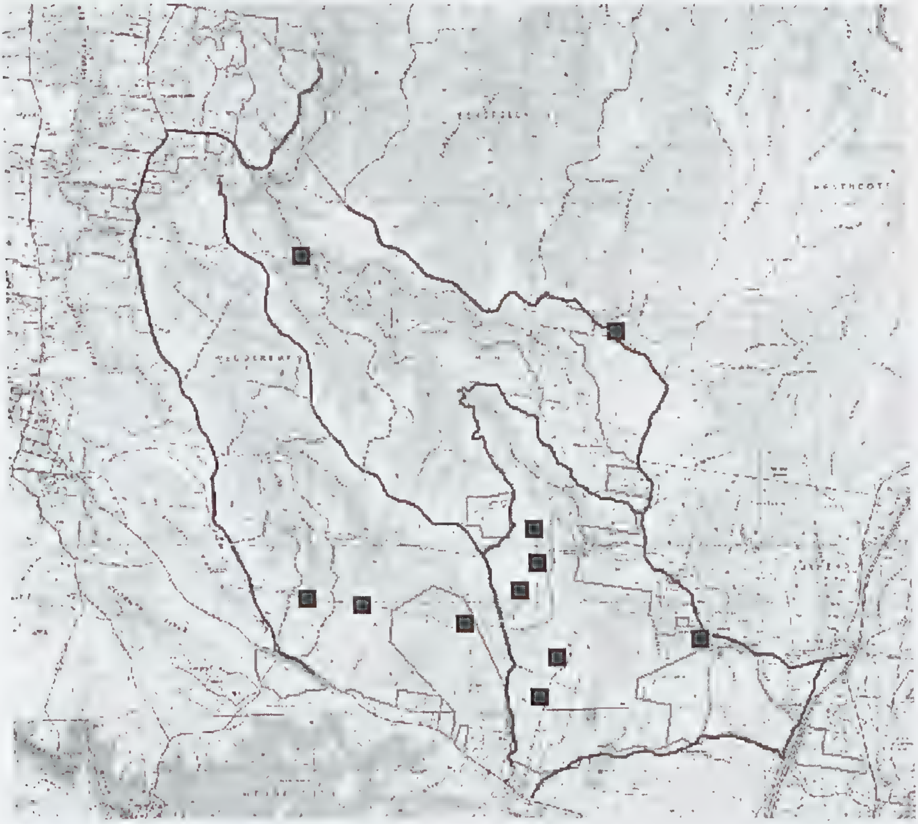


Figure 2. Approximate location of systematic survey sites (squares) in Dharawal reserves



consisting of Stringybark *Eucalyptus oblonga*, Scribbly Gum *E. racemosa*, Silvertop Ash *E. sieberi* and Red Bloodwood *Corymbia gummifera*. Other communities include upland swamps, upland swamps: sedgeland-heath, upland swamps: fringing eucalypt woodland Scribbly Gum *E. haemastoma* and Red Bloodwood, upland swamps: mallee-heath, Silvertop Ash ironstone woodland and rock plate heath mallee (Keith, 1994).

The O'Hares Creek Shale Forest Community is listed as an Endangered Ecological Community under the TSC Act (1995). It is characterised by the tree species *Eucalyptus globoidea*, Sydney Peppermint *E. piperita*, Sydney Red Gum *Angophora costata* and Red Bloodwood. Shrub species include *Acacia binervata, A. longifolia, Banksia spinulosa* and the Gymea Lilly *Doryanthes excelsa*. Approximately half of the community has been cleared for agriculture (orchards and grazing) or mining and only small remnant patches remain, totalling less than 200 hectares. Approximately 20-30 hectares of O'Hares Creek Shale Forest Community occurs within the Dharawal reserves (Department of Environment and Climate Change vegetation mapping).

SURVEY METHODS

Surveys for amphibians were undertaken between October 2006 and December 2008.

Table 1. Location of sites surveyed and survey effort.
Note: the roads in the survey area are named 10 with alphabetical suffixes. These names are used in the table.

Site name	Easting	Northing	Location	Survey 1	Survey 2	Survey 3	Survey 4
Dahlia Ck	306290	6214838	Continue along Darkes Forest Rd	18.20-18.50 h; 15.ix.06	19.40-20.10 h; 4.xi.07		
Four Mile Creek	300954	6210012	Wedderburn Rd then 10G	20.06-20.36 h; 14.ix.06		19.20-19.50 h; 22.ii.08	18.20-18.50 h; 20.ix.08
Iluka Creek A	305216	6210181	Off 10R trail	21.00-21.30 h; 13.ix.06			
Iluka Creek B	305314	6208790	Walk down old trail from 10B	21.52-22.07 h; 14.ix.06		19.40-20.10 h; 19.ii.08	
Iluka Creek C	305120	6210856	Off 10R trail		19.40-20.10 h; 3.xii.07		
Maddens Creek	308180	6209206	Service trail off Darkes Forest Rd		21.08-21.38 h; 4.xii.07		
O'Hares Creek	300836	6215972	10B then 10B to crossing		19.44-20.14 h; 26.xii.07		
Stokes Creek A	301990	6209910	10G then side trail to east	23.00-23.30 h; 13.ix.06		20.14-20.44 h; 22.ii.08	
Stokes Creek B	303752	6209720	10B then walk down trail - opp 10R			21.04-21.34 h; 19.ii.08	
unnamed creek	304029	6213041	10B then 10C		19.45-20.15 h; 24.xii.07		
Dam off road 10U	304783	6210286	Drive to end of 10U			19.40-20.10 h; 20.ii.08	

Habitat assessments were undertaken, which included site location, details of stream characteristics and the surrounding vegetation (Appendix 1) and the presence/absence of exotic fish (including yabbies as defined under the New South Wales Fisheries Act 1994). The location of each site was recorded using a global positioning system in AMG Datum 66, UTM co-ordinates in Zone 56 (Table 1).

Nocturnal searches

Ten creek sites were surveyed using nocturnal searches carried out along approximately 250 m of creek over 30 minutes and we carried out one to three surveys per stream. We used 50 watt/12 volt spotlights to observe frogs, tadpoles and spawn in the water and within 5 m of the bank. In addition the edge of one dam was surveyed in a similar fashion. If two people walked the same transect only one person recorded detections, the other assisted in observations and occupational health and safety requirements. Surveys were conducted over spring and summer in an attempt to detect as many species as possible (Table 1). The DECC hygiene protocol for frogs (2008) was followed.

Nocturnal searches were also conducted at ephemeral ponds, while walking to and from creek survey sites and by drive transects. Surveys were conducted after rain events in order to maximise detectability, although the survey period co-incided with extreme variation in rainfall, with below average rain (Australian Government Bureau of Meteorology website). Several species of frog breed in ephemeral ponds after rain and this habitat was located by the presence of calling frogs.

In general frogs were detected by recognition of species-specific calls. The total number of frogs recorded at a site was a tally of the number of calling males (a subset of these were observed) plus those observed that were not calling (females plus amplexed males). Generally frogs were not handled, however some animals were swabbed for pathology or captured to confirm identification.

Diurnal searches

Diurnal surveys involved walking along creeks, the dam and any recorded ephemeral ponds looking for frogs, tadpoles and spawn. The species of frog present were identified by call, direct observation, tadpoles or spawn masses. As tadpoles were more readily detectable at sites during the day than frogs, most species were identified by the presence of their tadpoles. Call imitation was also used to elicit calling by sheltering male frogs.

Pathology

Swab samples taken from frogs and tadpoles were sent to CSIRO laboratory in Geelong for PCR (polymerase chain reaction) testing for the chytrid. The excision, extraction and Taqman assay (Boyle *et al.*, 2004) were performed in a laboratory which had no prior exposure to chytrid and disposable equipment was used. The samples were analysed in triplicate and at two dilutions 1:2 and 1:10.

RESULTS

Survey sites, effort and species richness

Sixteen systematic surveys were conducted (Table 1) comprising eight hours nocturnal search effort. The number of frog species detected during systematic surveys at each site is detailed in Table 2. Sixteen species of frog were detected during the surveys, thirteen of which were found during streamside searches (Table 3).

Species diversity during a single survey event at sites ranged between 1-10. The highest diversity was recorded at Dahlia Creek. This site had a diversity of habitats including isolated pools surrounded by dense heath, exposed sandstone surrounded by woodland and pools of various depths. Twelve species were recorded at this site during two surveys.

The most abundant species was the Common Eastern Froglet *Crinia signifera* accounting for approximately 50% (135/276) of detections (Table 2). The most common tree frogs were the Blue Mountains Tree Frog *Litoria citropa*

Table 2. Number of adult frogs detected during systematic searches.

Litoria citropa = Lc, *Litoria dentata* = Ld, *Litoria phyllochroa* = Le, *Litoria freycineti* = Lf, *Litoria jervisiensis* = Lj, *Litoria littlejohni* =Ll, *Litoria lesueuri* = Lm, *Litoria peroni* = Lp, *Litoria tyleri* = Lt, *Litoria verreauxii* = Lv, *Crinia signifera* = Cs, *Heleioporus australiacus* = Ha, *Limnodynastes dumerilii* = Ld, *Limnodynastes peronii* = Lz, *Pseudophryne australis* = Pa, *Paracrinia haswelli* = Ph, *Uperoleia laevigata* = Ul, the non-endemic yabbie *Cherax destructor* = Cd. X indicates presence of yabbies or presence of tadpoles of specified frogs. Repeat surveys indicated by double entry of site in chronological order. Where adult frogs were detected the number of frogs is given priority over the presence of tadpoles.

Site Name	Lc	Ld	Le	Lf	Lj	Ll	Lm	Lp	Lt	Lv	Cs	Ha	Ld	Lz	Pa	Ph	Ul	Total Species	Cd
Dahlia Ck	7		3		1	3	2	1	1	1	20		2					10	
Dahlia Ck	2		2	8		X		2			9			2				7	
Four Mile Ck	8		2								10		1					4	
Four Mile Ck											5							1	
Four Mile Ck	9					1		1			15		X					5	
Iluka Creek A						1								1				2	
Iluka Creek B	1										5		1					3	
Iluka Creek B											5							1	X
Iluka Creek C	2	X		8		X						2	3					6	
Maddens Ck	8	1	8				3				3							5	
O'Hares Creek	1		6				2	4			6							5	
Stokes Creek A	3					2					23							3	
Stokes Creek A		X		X		X					15		X					5	X
Stokes Creek B	1										7							2	X
unnamed creek								2			4				1			3	
dam off 10U								1			8		2	3		10	5	6	
Total individuals = 276	42	1	21	16	1	7	7	11	1	1	135	2	9	6	1	10	5		

Table 3. Species of frog detected at Dharawal reserves and Darkes Forest.

Scientific Name	Common Name	This survey	DECC 2007a	Harlow and Taylor	AM record
Litoria aurea	Green and Golden Bell Frog				X
Litoria caerulea	Green Tree Frog				X
Litoria citropa	Blue Mountain Tree Frog	X	X	X	X
Litoria dentata	Bleating Tree Frog	X	X	X	X
Litoria fallax	Dwarf Tree Frog		X		X
Litoria freycineti	Freycinet's Frog	X	X	X	X
Litoria jervisiensis	Jervis Bay Tree Frog	X	X	X	X
Litoria latopalmata					X
Litoria lesueuri	Lesueur's Frog	X		X	X
Litoria littlejohni	Heath Frog	X	X		
Litoria nudidigitus			X		
Litoria peronii	Peron's Tree Frog	X	X	X	X
Litoria phyllochroa	Green Stream Frog	X	X	X	X
Litoria tyleri	Tyler's Tree Frog	X	X		X
Litoria verreauxii	Verreaux's Tree Frog	X	X	X	X
Litoria wilcoxii	Stony Creek Frog		X		
Crinia signifera	Common Eastern Froglet	X	X	X	X
Heleioporus australiacus	Giant Burrowing Frog	X	X	X	X
Limnodynastes dumerilii grayi	Pobblebonk	X	X	X	X
Limnodynastes peronii	Striped Marsh Frog	X	X	X	X
Paracrinia haswelli	Haswell's Frog	X	X		X
Pseudophryne australis	Red-crowned Toadlet	X		X	X
Pseudophryne bibronii	Bibron's Toadlet				X
Uperoleia laevigata	Smooth Toadlet	X	X	X	

with approximately 15% of detections and *Litoria phyllochroa* with approximately 8% of detections.

A repeat survey of Four Mile Ck A was undertaken on 22 February 2008 and 20 September 2008 to ascertain the identity of the Green Stream Frog. The call of this frog had been heard during the initial survey and had characteristics akin to *Litoria nudidigitus*. Although the calls of frogs during the second survey were not definitive a specimen photographed had markings that were akin to *Litoria phyllochroa* (less broad silver-gold canthus stripe).

The legs of frogs from the *Litoria lesueuri* species group were examined for colouration. All frogs found during the survey had blue spots in the leg folds; *Lit. wilcoxii* was not detected. All Pobblebonk frogs *Limnodynastes dumerilii* were examined and had characteristics typical of the subspecies *grayi*, being less than 50 mm in total length and with flanks suffused with lemon yellow (Barker *et al.*, 1995).

Three species currently listed under the TSC Act (1995) were found during the survey: *Litoria littlejohni, Pseudophryne australis* and *Heleioporus australiacus*.

Heath Frog

Litoria littlejohni was detected by the presence of tadpoles and calling males. Adults were detected at four sites, only one of which did not have tadpoles. Tadpoles were observed at an additional site where adults were not detected (Table 2). At one site that was surveyed during the day (a tributary of Stokes Creek beside the decommissioned electricity easement) approximately 120 tadpoles were found in several potholes/pools in a small section of the creek, just above a waterfall. No *Lit. littlejohni* tadpoles were found above or below the waterfall, being confined to approximately 30 m of creekline. At other

Table 4. Chytrid status of species of frog within Dharawal reserves

Note: a number samples were inhibited and several had a low number of zoospore equivalents in only one or two wells (from a total of three) and are defined as "indeterminate". These are not included in the total number of samples.

Scientific Name	Common Name	Chytrid	chytrid +ve/ No. samples
Litoria citropa	Blue Mountain Tree Frog	X	3/11
Litoria dentata	Bleating Tree Frog	-	0/4
Litoria freycineti	Freycinet's Frog	X	1/2
Litoria lesueuri	Lesueur's Frog	-	0/3
Litoria littlejohni	Heath Frog	X	5/5
Litoria peronii	Peron's Tree Frog	-	0/2
Litoria phyllochroa	Green Stream Frog	X	2/6
Crinia signifera	Common Eastern Froglet	X	1/6
Heleioporus australiacus	Giant Burrowing Frog	-	0/1
Limnodynastes dumerilii	Pobblebonk	X	1/3

sites tadpoles were in larger pools or gutters where the flowrate of the creek was reduced.

Litoria littlejohni tadpoles were only detected in the upper laterals of second and third order perennial creeks. These creeks were underlain by Hawkesbury Sandstone and at most sites the creek-side habitat varied from narrow races of water on exposed potholed bedrock to sandy ponds (up to 1 m deep). The water turbidity was low and the water clear.

The immediate vegetation beside the creeks was primarily Scribbly Gum woodland (to 6 m in height), which had a thick shrublayer of heath species (Table 1). The main canopy species were Scribbly Gum, Silvertop Ash and Red Bloodwood and the shrub layer consisted of Swamp Banksia *B. robur, B. oblongifolia,* Heath Banksia *B. ericifolia,* Needle-leaved Hakea *H. teretifolia* and sedges *Sprengelia incarnata* and *Bauera microphylla* (Keith, 1994). The vegetation communities of the area are described by Thomas *et al*. (2000) as forest ecosystems 137, 138 and 139 and by NPWS as mapping unit MU30 (NPWS, 2003). In general the surrounding country was escarpment plateau. The creeks had exposed areas of sandstone and shallow pools.

Giant Burrowing Frog

Heleioporus australiacus was detected at Iluka Creek C and opportunistically under a decommissioned transmission line. Iluka Creek C had exposed areas of sandstone and shallow pools. Two *H. australiacus* were heard calling during a systematic survey of this creek on 3 December 2007. A third *H. australiacus* was heard after the cessation of the survey. All three frogs were calling at a distance from the creek (approximately 50 m).

The immediate vegetation beside the creek near the decommissioned transmission line was Scribbly Gum woodland (to 6 m in height), which had a thick shrublayer of heath species (Table 1). The main canopy species at Iluka Creek C were Scribbly Gum, Silvertop Ash and Red Bloodwood. Heath and sedges were present in the shrublayer and at both sites there were areas of Coral Fern *Gleichenia microphylla* on the edge of the creeks.

Red-crowned Toadlet

One male *Ps. australis* was detected in the upper catchment of a tributary beside the road 10C. The woodland habitat in the immediate area included canopy species of Silvertop Ash, Sydney Red Gum and Red Bloodwood attaining 10 m in height and a shrub layer of Heath Banksia, *Pultenaea* and Drumsticks *Isopogon* spp.. Another individual male was found under leaf litter after it responded to a call imitation on 12 December 2008. This frog was close to the upper lateral of a creek that had formed as a consequence of a road being constructed. This site was surveyed on several occasions but was often dry. The surrounding area supported Sydney Red Gum and Sydney Peppermint woodland with heath species in the shrublayer.

Threatening agents

Chytrid fungus was detected on six species of frog including *Lit. citropa, Lit. freycineti, Lit. littlejohni, Lit. phyllochroa, C. signifera* and *Lim. dumerilii.* Swab samples taken from four species of frog, *Lit. dentata, Lit. lesueuri, Lit. peroni* and *H. australiacus*, did not indicate the presence of chytrids (Table 4). The pathogen is widespread and present in several species of tree frog and ground dwelling frog in the O'Hares and Maddens Creek catchments.

The Plague Minnow *Gambusia holbrooki* was observed in the lower catchment of Stokes Creek in the vicinity of the weir. Although Stokes Creek forms a portion of the catchment of O'Hares Creek no Plague Minnow were observed at one creek crossing at O'Hares Creek. No Plague Minnow were observed at any of the survey sites within the upper catchments of the reserves.

DISCUSSION

Species diversity and habitat

Seventeen species of frog were detected during this survey, fifteen of which were found while conducting streamside searches. Some of these species are facultative lotic breeders including *Heleioporus australiacus, Ps. australis* (seepages), *Lit. citropa, Lit. lesueuri* and *Lit. phyllochroa*. Two species, *Uperoleia laevigata* and *Paracrinia haswelli*, were only detected beside a dam within the reserves. The other species are known to use ponds/dams or pools within creeks for breeding (Anstis, 2002).

The species diversity of streams was quite variable and ranged from one to ten species per survey. The site at Dahlia Creek supported a total of 12 frog species. This diversity of frogs was greater than that recorded for any site during systematic surveys published for NSW south of Sydney (Daly *et al.*, 2002; Daly, 2006; Daly & Craven, 2007). More species were detected at sites where heath-woodland bordered creeks that had extensive areas of relatively flat exposed bed rock, overhangs and deep (greater than 0.6 m) pools and potholes. This finding is consistent with other studies (Daly, 2000, 2006; DECC, 2007a,b). The least number of frogs was found where exposed rock and shallow pools/riffle zones were absent and heath grew to the edge of the creeks.

In a review of the fauna of Dharawal reserves the Department of Environment and Climate Change (DECC, 2007a) state that the Southern Green Stream Frog *Lit. nudidigitus* (based on call) and the Stony Creek Frog *Lit. wilcoxii* occur in the region. Neither species were detected during this survey. However, the calls of *Lit. phyllochroa* at Four Mile Creek appeared to be that of *Lit. nudidigitus* but the colouration of an adult was akin to *Lit. phyllochroa*. Only the subspecies of Pobblebonk *Lim. dumerilii grayi* was detected, although there are records of *Lim. dumerilii dumerilii* on the National Parks Wildlife atlas as occurring in the area.

Other species that have been listed by DECC (2007b) as occurring in the region are either rare (*Lit. caerulea*), or species that breed in seasons outside of our survey period (*Pseudophryne bibronii*) or are highly associated with the farm dams in this region (*Lit. fallax*). The presence of *Lit. fallax* in the Darkes Forest area may have been from translocated animals. To the west of the reserves, this species has been detected around dams on the Wianamatta Shale of the Cumberland Plain (G. Daly, unpubl. data). This species has recently expanded its range east of Darkes Forest to the coastal village of Stanwell Park. One of us (GD) lived at Stanwell Park from 1978-1987 and visits the area at least six times per year, yet *Lit. fallax* was only detected in 2008. The Spotted Grass Frog *Lim. tasmaniensis* has also been detected to the west of Dharawal reserves on the Cumberland Plain (G. Daly, unpub data) and it may occur on the western edge of the reserves.

Adult *Lit. freycineti* were detected during systematic streamside searches at two sites and a flooded shallow swale beside the road that crosses Maddens Creek. *Litoria freycineti* is considered common within the reserves with over thirty animals observed. In contrast single animals were detected at two sites in Morton NP, some 90 km to the south (Daly, 2006).

Threatened species – habitat and status

Mixophyes balbus and *Lit. aurea* occurred in the Dharawal reserves, but now appear to be extinct. There has been a marked decline in the distribution and abundance (south of Sydney for *M. balbus*) of these species over the last thirty years (DEC, 2005; Daly *et al.*, 2002). Wild populations of *M. balbus* appear to be extinct south of Sydney (Daly & Craven, in prep.)

The presence of the frog fungus chytrid may be implicated in these declines. Although not listed under the TSC Act (1995), the Green Tree Frog *L. caerulea* is rare in the Illawarra

(DECC, 2007a) and is considered to have suffered a marked decline in abundance and distribution over the last forty years (Harrison, 1922; G. Daly, pers. obs.). Populations in the region are considered small, fragmented and endangered by the senior author. *Litoria caerulea* may no longer persist in the Darkes Forest/Dharawal area, with the last record in 2001 (NPWS wildlife atlas).

Litoria littlejohni was detected at seven sites during this survey and is widely distributed over the reserves. The number of tadpoles indicated breeding had occurred and several clutches had been laid at certain sites. The number of adult frogs was relatively low compared to that found in the Shoalhaven (Daly, 2006; Daly & Craven, 2007), but this may be an artefact of the survey period of this study. This species rarely calls during summer; breeding has been demonstrated to occur primarily during late winter and spring (Daly & Craven, 2007). At some sites the species was only detected by the presence of tadpoles and this method is considered highly appropriate for assessments where presence of a species is necessary.

Litoria littlejohni were heard calling from beside sections of creek surrounded by dense heathland but higher densities were in woodland with heath shrublayer and sections of creek that flowed over exposed rock. This habitat was similar to that described by Daly and Craven (2007) where this species was studied in Morton NP, although the substrate in the present study was Hawkesbury Sandstone as opposed to Nowra Sandstone. In the Illawarra and adjoining Shoalhaven area a suite of animals including *Lit. littlejohni* use sites supporting suitable habitat, in this case woodland/heathland on sandstone, irrespective of geological unit (Daly, 2006).

Heleioporus australiacus were detected at two sites, which broadly overlapped those where *Lit. littlejohni* were detected. The northern form of *H. australiacus* and *Lit. littlejohni* have similar habitat requirements (Daly, 1996; Penman *et al.*, 2004). Although tadpoles of *H. australiacus* had been detected in the upper catchment of Stokes Creek (K. Madden, pers. comm.) they were not found during these surveys. The absence of *H. australiacus* tadpoles indicates that this species may breed in response to specific environmental conditions, such as heavy rainfall during autumn (Daly, 1996).

Pseudophryne australis was detected at two sites in the upper laterals of first order creeks on sandstone. The sections of these creeks were non-perennial and were mostly dry during the investigation. The vegetation in the areas where the animals were found was forested (Thomas *et al.*, 2000). *Pseudophryne australis* has its southern limit in the Illawarra and recent surveys suggest that the limit of distribution is north of Barren Grounds NR (Gaia Research, 2008).

Threatening processes

Chytrid is widespread and present in a number of species of frog within the Dharawal reserves. During this survey, all measures were taken to ensure that we did not inadvertently spread the pathogen further. It should be noted that the hygiene protocols outlined by DECC (2008) are not adhered to by researchers who do not work on frogs. The stringent measures employed by us during the surveys may serve no useful purpose if other workers are freely able to transmit the pathogens about the site. Chytrid is widespread in many environments and all species that tested positive for the pathogen during this survey appeared healthy.

If chytrid was introduced into Australia around 1978 (Speare & Berger, 2000) then most species of frog on the east coast south of the Big Tableland in north Queensland have co-existed and evolved with the disease for several generations. Those species that appear to be highly sensitive to the chytrid (such as *M. balbus* and *Lit. aurea*) are now absent from sites where the pathogen is present or appear to persist at sites where the fungus is mediated by other factors (Daly *et al.*, 2008; Osborne *et al.*, 2008; Threlfall *et al.*, 2008).

The Plague Minnow *Gambusia holbrooki* was detected in the lower portion of Stokes Creek but also exists within O'Hares Creek above the junction with Stokes Creek (Knight & Bruce, 2008). The sites surveyed were in the upper reaches of the catchment and often above waterfalls. There appears little opportunity for this fish to penetrate into these sections of the catchment because of these physical barriers. On this basis this species is not considered to be a threatening agent in the reserves.

The yabbie *Cherax destructor* is considered a major threat to all species of lotic frog within the region (Daly & Craven, 2007; Coughran *et al.*, in press). This yabbie eats the eggs of frogs and can move over obstacles such as waterfalls and has penetrated the O'Hares Creek upper catchment. The yabbie may have a devastating impact on *Lit. citropa, Lit. lesueuri, Lit. littlejohni, Lit. phyllochroa, H. australiacus* and *Lim. dumerilii* as these species breed within creeks and some are facultative stream breeders. Results from this study form the basis of future monitoring. The yabbie may also impact on populations of the endemic Sydney crayfish *Euastacus spinifer* as other species of endemic crayfish have been shown to have declined after *C. destructor* was been liberated into catchments (Coughran *et al.*, in press). Currently no control mechanisms can be applied to eradicate this species.

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Appendix. Site attributes for stream-side searches.

DECC Region:	Site No/Creek Name:
Date:	Surveyor:

Locality description:

Map code: Map Name. AMG Zone.

AMG or GDA transect/site Start E: _ _ _0 N_ _ _0 Fin Start E: _ _ _0 N_ _ _

Land Tenure (circle): Nat. Park State Recreation Area Private Local Council

LGA name: NPWS District: Altitude. (m asl).

Topographic Position: flat escarpment edge mid escarpment plateau upper escarpment plateau

Geology **Soil** shallow skeletal **Type** sand or clay

Fish Present Eels Spotted Galaxia Climbing Galaxia Gudgeons Yabbie (Euastacus - Cherax) Gambusia

Stream characteristics (circle)
or
Pond or gutter beside road
Dam

Stream Order	1	2	3	
Stream Width	m			
Stream Substrate	gravel	rock	sand	clay
Fringe Vegetation	ferns	sedges	Todea	Dicksonia
Water	still	moving	permanent	ephemeral
	potholes	overhangs	riffle zones	pools

Disturbance	Severity (0 = no evid, 1= light, 2 = mod., 3 = severe	Time since last event (estimated)	Accuracy (eg +/_ years)	Obs. Type 1 = visual, 2 = written, 3 = informant (who)
Fire				
Logging				
Weeds				
Flood				

Vegetation	Species	Height (m)	Aquatic plants
Emergent			
Upper tree layer			
Second layer			
Shrub			

MALE CYCLE OF THE MILITARY SAND-DRAGON, *CTENOPHORUS ISOLEPIS*, FROM WESTERN AUSTRALIA

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INTRODUCTION

The Military Sand-Dragon, *Ctenophorus isolepis*, occurs from central coastal regions of Western Australia to Central Australia and western Queensland and frequents a variety of arid and desert habitats, usually closely associated with spinifex or porcupine grass (*Triodia* spp.) (Cogger, 2000). Previous information on reproduction of *C. isolepis* is provided by Pianka (1971a, 1986) and Saint Girons *et al.* (1992). The purpose of this paper is to add information on the timing of events in the testicular cycle of *C. isolepis* from a histological examination of gonadal material. The possibility of geographic variation in reproduction of *C. isolepis* is discussed.

METHODS

One-hundred and seventy two males of *C. isolepis* (mean snout-vent length, SVL = 51 mm ± 4 SD, range = 43-66 mm) deposited in the Natural History Museum of Los Angeles County (LACM), Los Angeles, California, USA were examined (see Appendix). Lizards were collected between 26°04'S to 31°02'S and 119°10'E to 127°35'E in Western Australia by Eric R. Pianka in 1966-67. These same specimens were utilized in an ecological study on *C. isolepis* by Pianka (1971a) who did not perform histological examination. Testes were dehydrated in ethanol, embedded in paraffin, sectioned at 5 μm and stained with Harris hematoxylin followed by eosin counterstain.

I divided the testicular cycle of *C. isolepis* into five stages (Table 1): (1) Regressed, seminiferous tubules are dominated by spermatogonia and Sertoli cells. Occasional residual sperm from the last period of sperm production may remain. Germinal epithelium is one to two cell layers thick; (2) Early recrudescence, proliferation of germinal epithelium for the next period of sperm production has commenced, spermatogonia and primary spermatocytes predominate; (3) Late recrudescence, seminiferous tubules exhibit increased cellularity, with the appearance of secondary spermatocytes and spermatids; (4) Maximum spermiogenesis, lumina of seminiferous tubules are lined by mature spermatozoa, groups of metamorphosing spermatids are present; (5) Late or residual spermiogenesis, germinal epithelium cellularity is markedly reduced in comparison to stage 4, small groups of spermatozoa and/or metamorphosing spermatids remain.

RESULTS

The smallest males undergoing spermiogenesis measured 43 mm SVL (LACM 54374, 54672) and were from February and August, respectively. The main seasonal timing for maximum spermiogenesis occurred from September through January when 100% of 107 males were producing sperm. Spermiogenesis was completed in February when males with regressed testes were recorded although males undergoing late (residual) spermiogenesis were found as late as May. Recovery (recrudescence) culminating with renewed sperm production began in March. By spring (September) all males exhibited peak spermiogenesis.

DISCUSSION

In general, members of the genus *Ctenophorus* (Johnston, 1999; Goldberg, 2007, 2009; Pianka, 1971b) most closely fit the Type I category of Heatwole and Taylor (1987) with spring sperm production and ovulation.

Table 1. Monthly stages in the testicular cycle of 172 *Ctenophorus isolepis* from Western Australia.

Month	n	Regressed	Early recrude-scence	Late recrude-scence	Maximum spermio genesis	Late spermio genesis (residual)
September	24	0	0	0	24	0
October	22	0	0	0	22	0
November	26	0	0	0	26	0
December	16	0	0	0	16	0
January	17	0	0	0	17	0
February	7	2	0	0	4	1
March	4	1	1	1	0	1
May	16	1	4	1	0	10
August	40	0	3	18	19	0

However, there is evidence of geographic variation in the reproductive cycle of *C. isolepis*. Saint Girons *et al.* (1992) reported that reproduction was concentrated from January to March or April in *C. isolepis* from the Pilbara region (20°53'S 118°02'E) of northern Western Australia. However, they reported that one October male collected further south at Wittenoom (22°30'S 118°30'E) had already commenced spermiogenesis. Pianka (1971a), who studied *C. isolepis* from further south (26° to 31°S), published a graph in which testes were at maximum lengths in aestival spring-early summer (September to November and January) concurrent with maximum spermiogenesis in my paper (Table 1). Testes had smallest lengths (Pianka, 1971a) when testes were regressed or in recrudescence in my study (Table 1).

In conclusion, my histological findings utilising specimens of Pianka (1971a) along with his morphometric data indicate reproduction commences in spring at lower latitudes of Western Australia, whereas the findings of Saint Girons *et al.* (1992) indicate *C. isolepis* reproduction occurs in summer in northern Western Australia. These findings indicate geographic variation occurs in the reproductive cycle of *C. isolepis* with the onset of reproduction being delayed in the north. Subsequent investigations in different populations of *C. isolepis* are needed to clarify the geographic variations in its reproductive cycle. The question of geographic variation in reproduction should also be considered for other Australian agamids as Saint Girons *et al.* (1992) indicated there was latitudinal variation in the timing of reproduction for *C. nuchalis* and Goldberg (2009) for *C. caudicinctus*.

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Appendix: *Ctenophorus isolepis* examined from Western Australia deposited in the Natural History Museum of Los Angeles County (LACM).

LACM 54339, 54347, 54350, 54351, 54354, 54355, 54358, 54361, 54362, 54368, 54371, 54374, 54378, 54379, 54384, 54386-54389, 54391-54393, 54395-54397, 54399, 54400, 54402-54404, 54407, 54409, 54411-54414, 54417, 54419, 54421, 54422, 54427, 54428, 54432, 54434, 54439, 54440, 54443, 54446, 54448, 54454, 54455, 54458, 54460, 54461, 54464, 54468, 54469, 54472, 54473, 54483-54486, 54490, 54491, 54493, 54494, 54496, 54499, 54502, 54504, 54508, 54511, 54516, 54518, 54519, 54521, 54524, 54525, 54530, 54536, 54540, 54546, 54547, 54569, 54571-54573, 54575, 54577, 54583, 54585, 54587, 54591, 54592, 54594, 54595, 54597-54600, 54603, 54609-54611, 54618, 54623, 54625, 54628-54630, 54632, 54638, 54653, 54656, 54657, 54664, 54668, 54669, 54672, 54679, 54685, 54746, 54748, 54749, 54751-54753, 54755, 54757, 54758, 54763-54765, 54768, 54771, 54772, 54774, 54775, 54778, 54779, 54781, 54784, 54792-54794, 54798, 54802, 54804, 54807-54809, 54818-54820, 54825, 54828, 54831-54833, 54835, 54836, 54846, 54847, 54850, 55196, 55202-55204, 55208, 55210, 55217.

THE REDISCOVERY OF THE BRONZEBACK SNAKE-LIZARD *OPHIDIOCEPHALUS TAENIATUS* (LUCAS AND FROST, 1897) IN THE NORTHERN TERRITORY AFTER A 111 YEAR ABSENCE OF RECORDS

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The Bronzeback snake-lizard *Ophidiocephalus taeniatus* was described in 1897 by Lucas and Frost from a specimen taken by Paddy Byrne at Charlotte Waters, located in what is now the Northern Territory. Since its rediscovery in South Australia in 1978 (Ehmann & Metcalfe, 1978), *O. taeniatus* has been recorded from a number of scattered localities in the stony deserts of central and northern SA (Brandle, 1998; Brandle *et al.*, 2005; Downes *et al.*, 1997). Ehmann (1981) has also suggested that the species would occur at numerous sites in the Finke River drainage basin of the NT. However, despite considerable fauna sampling effort throughout the Finke Bioregion (Neave *et al.*, 2004) and the Finke River floodout area (Eldridge & Read, 1998), no animals had been located in the NT since the type specimen.

On 13 June 2008, at approximately 0850 hours, *O. taeniatus* was rediscovered in the Northern Territory during a survey for threatened Acacias. I uncovered a single animal whilst opportunistically raking the litter mat underneath a mature *Acacia aneura*. The individual was caught and then identified by the absence of an obvious ear-opening (the small ear-opening is covered by a temporal scale) and the distinctive bronze dorsal colouration. Several photographs were taken of the animal (Figure 1) before it was released at the site of capture.

The capture site (Figure 2) was on an elevated bank adjacent to upper Coglin Creek, in the southwest corner of New Crown Pastoral Lease (25°58'S 134°16'E, WGS 84). Vegetation consisted of *Eucalyptus coolabah* over *Acacia aneura* and *A. sibirica*, with a sparse groundcover of soft grasses and forbs. Shale and siltstone mesas dominate the surrounding area.

The rediscovery of *O. taeniatus* in the NT is particularly important due to the 111 year absence of any records and the doubt sur-

Figure 1. The first *Ophidiocephalus taeniatus* recorded in the NT in 111 years.

Figure 2. The *O. taeniatus* capture site, adjacent to upper Coglin Creek.

rounding the exact collection site of the type specimen (Ehmann, 1981). Habitat similar to that present at the capture site occurs over a considerable area of New Crown Pastoral Lease and also to the west on the neighbouring Umbeara Pastoral Lease. More intensive work is currently being undertaken to define the extent of its range in the area and to identify any immediate threats.

ACKNOWLEDGMENTS

I would like to thank the Costello family for granting access to New Crown Pastoral Lease. Thanks also to Catherine Nano for allowing me to take a break from a hectic survey schedule in order to rake litter and to Greg Fyfe for reminding me to pack a rake 'just in case'.

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NOTES ON THE DELICATE SKINK *LAMPROPHOLIS DELICATA* OCCURRING ON LORD HOWE ISLAND

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The Lord Howe Island Group is situated in the South Pacific Ocean, some 760 kilometres north-east of Sydney. The largest island in the group is Lord Howe Island itself, which is approximately 11 km long and 2.8 km wide at its widest point, covering an area of 1455 hectares (Department of Environment and Climate Change (DECC), 2007). As a result of its isolated location many flora and fauna species present are endemic. There are no endemic reptiles; however, two lizards are confined to the Lord Howe Island Group and some small islands within the Norfolk Island Group located approximately 900 km to the north-east. These species are the Lord Howe Island Gecko *Christinus guentheri* and the Lord Howe Island Skink *Cyclodina lichenigera* (Cogger, 1971; Cogger *et al.*, 1983). In 1995, the Delicate or Rainbow Skink *Lampropholis delicata* was first recorded on the island (Hutton, 1998; Hutchinson *et al.*, 2005) and subsequent genetic studies indicate that there have been multiple introductions from a number of locations on mainland Australia (D. Chapple, pers. comm.). By 1997 this skink was well established and widespread in the north of the island but occurred at low densities (A.H. Whitaker cited in Lever, 2003). The introduction of this skink follows earlier introductions to: a) the North Island of New Zealand in the 1960s with it now being widely established in the Greater Auckland area, Coromandel Peninsula, Tauranga and Te Puke regions, and expanding into new areas such as the Waikato, Wanganui, Whakatane and Whangarei regions (Peace, 2004; New Zealand Herpetological Society, 2008) and b) Hawaiian Islands where it was introduced about 1900 in Oahu and is now the most numerous skink across all the larger islands (Baker, 1979; Lever, 2003). In New Zealand, it is the only introduced reptile that has successfully established in the wild, while in Hawaii it is formally called the Plague Skink. Surprisingly little has been documented of the current occurrence of this skink on Lord Howe Island. This note summarises observations of this species on Lord Howe Island between 18 and 25 January 2009.

Lampropholis delicata was found to be widespread in all vegetation communities visited in lower elevation areas in the northern part of the island, south to Boat Harbour on the east coast and Lovers Bay on the west coast (Table 1). However, unlike the previous observations of A.H. Whitaker in 1997, this lizard was in some places found at high densities. Rough density estimates were derived from moving slowly along a known length of walking track and counting all observed individuals up to 1 m either side of the track under suitable conditions of little wind, sunny conditions with no rain on 24 and 25 January 2009. Individuals were encountered on the ground, on logs and rocks and on the sides of trees and in bushes up to 1 m above the ground. Density estimates on each track surveyed were derived by averaging the number of individuals per 100 m² from the total recorded along the length of track within the same broad vegetation community (after Pickard, 1974; Table 1). The highest densities were recorded in Greybark *Drypetes deplanchei* ssp. *affinis*-Blackbutt *Cryptocarya triplinervis* forest along the North Bay-Old Settlement Track (39.0 individuals/100 m²) and along tracks in the Muttonbird Point area (11.2-11.9 individuals/100 m²). However, densities within this vegetation community varied with lower densities recorded elsewhere such as 2.3 individual/100 m² on the lower Goat House Track and 0.3 individuals/100 m² on the Neds Beach-Ebbtide Track. The low density in the latter locality may be

associated with greatly disturbed ground layer due to the presence of an extensive Flesh-footed Shearwater *Puffinus carneipes* colony and the presence of numbers of the Buff-banded Rail *Gallirallus philippensis* that was observed to prey on this species (see below). Other vegetation communities appeared to support lower densities, such as Kentia Palm *Howea forsteriana* forest (1.5-2.5 individuals/100 m^2), Screw Pine *Pandanus forsteri* forest (2.5 individuals/100 m^2) and Coastal Tussock Grass *Poa poiformis* grassland (4.0 individuals/100 m^2). No densities assessments were made in Tea Tree *Melaleuca howeana*-Bully Bush *Cassinia tenuifolia*-Hop Bush *Dodonaea viscosa* scrub and in clearings and disturbed vegetation. In all habitats juveniles were observed but the proportion of these individuals to adults was not assessed.

Birds were observed preying on *L. delicata* on two separate occasions. The first observation was of a Buff-banded Rail grabbing an adult skink and feeding it to a chick on the ecotone of disturbed rainforest and mowed grass at the property 'Ebbtide'. This bird has increased significantly over the last 10 years and may account for the few skinks encountered in disturbed areas around the settlement where this rail is now commonly observed (DECC, 2007). The second observation was of the Lord Howe Island Currawong *Strepera graculina crissalis* seen swooping several times before successfully catching an adult skink on the Muttonbird Point Track. The Buff-banded Rail has not been recorded preying on lizards but has been observed catching frogs (Higgins *et al.*, 2006) while the mainland Pied Currawong *Strepera graculina graculina*, closely related to the Lord Howe Island Currawong, has been recorded feeding on small lizards, such as the Grass Skink *Lampropholis guichenoti* (Marchant & Higgins, 1993). It is likely that the Australian Kestrel *Falco cenchroides* also preys on this lizard where it occurs in open situations, such as pastureland, forest ecotone and *Poa poiformis* grassland. Other potential predators include the endemic Lord Howe Woodhen *Tricholimnas sylvestris*, the Sacred Kingfisher *Todiramphus sanctus* and the self-introduced exotic Common Blackbird *Turdus merula*.

In the Hawaiian Islands the establishment of *L. delicata* coincided with a marked decline of the Azure-tailed Skink *Emoia impar* and the Moth Skink *Lipinia noctua* (Lever, 2003). In New Zealand the species may be competing with the endemic Copper Skink *Cyclodina aenea* (New Zealand Herpetological Society, 2008), although a captive study did not reveal any direct contact between the two species and observed individuals did not appear to avoid each other spatially (Peace, 2004). The impact of this species through competition on remnant populations of *Christinus guentheri* and *Cyclodina lichenigera* on Lord Howe Island is unknown. Additionally, the high densities of this relatively newly introduced skink are of concern through predation of the threatened endemic invertebrate fauna, with a large percentage of these invertebrates occurring below 300 m in altitude or with restricted distributions on the island (DECC, 2007). The accidental introduction of *L. delicata* and the Bleating Tree Frog *Litoria dentata* (DECC, 2007) highlights the need for stringent quarantine procedures to insure against the introduction of additional reptile species such as the Asian House Gecko *Hemidactylus frenatus* and various snake species. There are occasional sightings every ten years or so of other unidentified lizard species around the settlement, most likely originating from stowaways, although no additional species appear to have become established (I. Hutton, pers. comm.). The impacts of such introductions are extremely difficult to reverse if they were to become established, thereby placing further pressures on the island's unique fauna.

Table 1. Location and densities of *L. delicata* in vegetation communities visited on Lord Howe Island. *Vegetation communities after Pickard (1974).

Vegetation Community*	Locations	Numbers Encountered	Density (per 100 m²)
Greybark *Drypetes deplanchei* ssp. *affinis*-Blackbutt *Cryptocarya triplinervis* forest	North Beach-Old Settlement Beach Track	273 in 350 m of track	39.0
	Sections of Malabar-Kims Lookout Track	Not assessed	Not assessed
	Malabar Track	81 in 500 m of track	8.1
	Transit Hill Track	Not assessed	Not assessed
	Lagoon Road to Muttonbird Point Track	157 in 700 m of track	11.2
	Section of Track: Muttonbird Point-Rocky Run	119 in 500 m of track	11.9
	Lower Goat House Track	18 in 400 m of track	2.3
	Sections of Rocky Run-Boat Harbour Track	Not assessed	Not assessed
	Neds Beach-Ebbtide Track	1 in 200 m of track	0.3
Scalybark *Syzygium fullargarii*-Blueplum *Chionanthus quadristamineus* forest	Section of Transit Hill Track south to Blinky Beach	Not assessed	Not assessed
	Section of Track: Rocky Run to Smoking Tree Ridge	18 in 500 m of track	1.8
Kentia Palm *Howea forsteriana* forest	Section of North Beach-Old Settlement Beach Track	15 in 300 m of track	2.5
	Section of North Bay-Old Gulch Track	3 in 100 m of track	1.5

Vegetation Community*	Locations	Numbers Encountered	Density (per 100 m²)
Screw Pine *Pandanus forsteri* forest	Section of Track: Rocky Run to Smoking Tree Ridge	10 in 150 m of track	3.3
Tea Tree *Melaleuca howeana*-Bully Bush *Cassinia tenuifolia*-Hop Bush *Dodonaea viscosa* scrub	Sections of Malabar-Kims Lookout Track Malabar Track near summit	Not assessed Not assessed	Not assessed Not assessed
Coastal Tussock Grass *Poa poiformis* grassland	Middle Beach South end of Blinky Beach	8 in 100 m on beach edge Not assessed	4.0 Not assessed
Clearings and disturbed vegetation	Disturbed vegetation in 'Ebbtide' garden Pastureland start of Clear Run Track	Not assessed Not assessed	Not assessed Not assessed

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DIPORIPHORA REGINAE (SQUAMATA: AGAMIDAE) IN SOUTH AUSTRALIA

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ABSTRACT

Collections in widely separated parts of the southern interior of South Australia document *Diporiphora reginae* as far east as the Lake Acraman area, a range extension of over 1,000 km east of its former narrow distribution. *Diporiphora reginae* inhabits similar *Triodia*-mallee habitats in the three areas in which it has been found, and the fact that this habitat forms a broadly continuous band across the southern Great Victoria Desert suggests that it may occur in other parts of this still poorly explored region of South Australia and south-eastern Western Australia.

INTRODUCTION

Diporiphora reginae was described by Glauert (1959) based on five specimens from "Karin [=Kalin] Rock, 14 miles from Cunderlee [=Cundeelee] Mission". Kalin Granite Rock is approximately 40 km SW of Queen Victoria Spring, and about 175 km east of Kalgoorlie. The new species was distinctive in its strongly keeled dorsal and ventral scales, and coloration in life, with a pair of bright yellow dorsolateral stripes and bright red colouration on either side of the base of the tail. Glauert assumed this bright colour to be the breeding colouring of males. ("nuptial dress").

Following this description, relatively few additional specimens have been added to collections. Storr's comment that the species is confined to a "small part of [the] arid southern interior of Western Australia, from Goddard Creek south-west to the Frazer Range" (Storr, 1974: 140) continues to be the accepted range of this species (Wilson & Swan, 2008). Storr *et al.* (1983) and Bush *et al.* (2007) illustrate specimens from the vicinity of Buningonia Spring and Queen Victoria Spring, showing the distinctive bright red tail base noted by Glauert. When *Diporiphora linga* (Houston, 1977) was described from the southern mallee of western South Australia, Houston noted the ecological similarity but also the obvious morphological differences that separated the new South Australian species from *D. reginae*. These include *D. linga's* weakly keeled, almost smooth dorsal scalation, compared with the strongly keeled and mucronate scalation in *D. reginae*, more complex back pattern and male breeding colouring of diffuse reddish colour along the dorsolateral region of the body extending on to the tail.

Aside from these basic taxonomic treatments, the species has scarcely rated a mention regarding any aspects of its biology or distribution. Ecologically, information seems to be limited to general statements that it lives in "spinifex/heath associations on sandy soils" (Wilson & Swan, 2008: 344).

SOUTH AUSTRALIAN RECORDS

The first South Australian sighting of the species was two specimens flushed from burning *Triodia* (A. Skinner, pers. comm.) on 16 April, 2005. One of these was collected (SAMA R60396). It is an adult male (SVL 57 mm), and when brought alive to the South Australian Museum showed the characteristic male breeding colour of lemon yellow dorsolateral stripes and bright red on the base of the tail. The locality is on the track from Oak Valley (South Australia) to Tjuntjuntjarra (Western Australia), approximately 7 km east of the Western Australian border. The habitat in the area is sand dunes with *Triodia* and

mallee overstorey (SA Dept of Environment and Heritage survey site number TJU 009).

This record represented a significant range extension eastwards, and suggested that the largely unexplored terrain between Oak Valley and Queen Victoria Spring might support other populations of this species, as the habitat is typical of much of this region of Western Australia.

The second records are from much further east. In October 2006, a party from the South Australian Museum, supported by members of the Waterhouse Club, conducted a fauna survey on Moonaree Station, on the northern edge of the Gawler Ranges, adjacent to the northeastern edge of Lake Acraman. *Diporiphora reginae* specimens were commonly seen in sandy areas supporting dense strands of *Triodia* with a mallee overstorey (Figure 1). Two specimens, an adult male (SAMA R61980; SVL 60 mm) and an immature specimen (SAMA R61995; SVL 40 mm), were collected. Observations of *D. reginae* were also made on a *Triodia* hummock grassland on a porphyritic granite outcrop (DEH site number ACR 006) surrounded by a dune field with *Triodia*-mallee. When disturbed the *D. reginae* would either retreat quickly back into the *Triodia* or into cracks between rocks (J.E., pers. obs.). Further searching of other granite outcrops north of ACR006 failed to locate any individuals. Moonaree Hill was also searched and although the environment was similar to ACR006, no *D. reginae* were sighted. Moonaree Hill was surrounded by chenopod (*Atriplex* and *Maireana* spp.) plains. *Diporiphora reginae* was predominantly observed in mallee dunes covered by dense strands of *Triodia* that had not been burnt for at least fifty years. At other sites, where the stands of *Triodia* were sparser, no individuals were caught or observed.

During November 2006, a third observer (P. Tremul, pers. comm.) visited the area and photographed individuals of *D. reginae* (Figure 2) on Moonaree Station and then specimens of *D. linga* a short distance east of Moonaree at a location to the northwest of

Figure 1. Sand dune mallee with old *Triodia* understorey, Moonaree Station, South Australia, where *D. reginae* was collected and observed (Photo: J. Eaton).

Lake Acraman. The two localities are approximately 60 km apart and have similar sandy *Triodia*-mallee habitat.

The distribution of *D. reginae* is shown in Figure 3. The new information on this species is mirrored to a degree by recent identification in Western Australia of *Diporiphora linga*, previously known only from the southern interior of South Australia (Figures 3-4; Wilson & Swan, 2008; P. Doughty, pers. comm.). Up to the end of the 20th Century, the *Triodia*-mallee habitat of the southern Great Victoria Desert and adjacent Bungalbin and Yellabinna sand plains was thought to support two allopatric species of *Diporiphora: D. reginae* in the west and *D. linga* in the east. It now appears that the two may both occur across this habitat block. Both *D. linga* and *D. reginae* are known from around Queen Victoria Spring, and from the northern end of Lake Acraman but there are no records of *D. reginae* from the Yellabinna locations where *D. linga* has been recorded (Figure 3). Further fieldwork directed at finding additional populations of *D. reginae* would be highly desirable, as would observations directed at ecological factors that correlate with the occurrence of either or both of these species.

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Figure 2. Male *Diporiphora reginae* photographed in the field, Moonaree Station, South Australia. (Photo: P. Tremul).

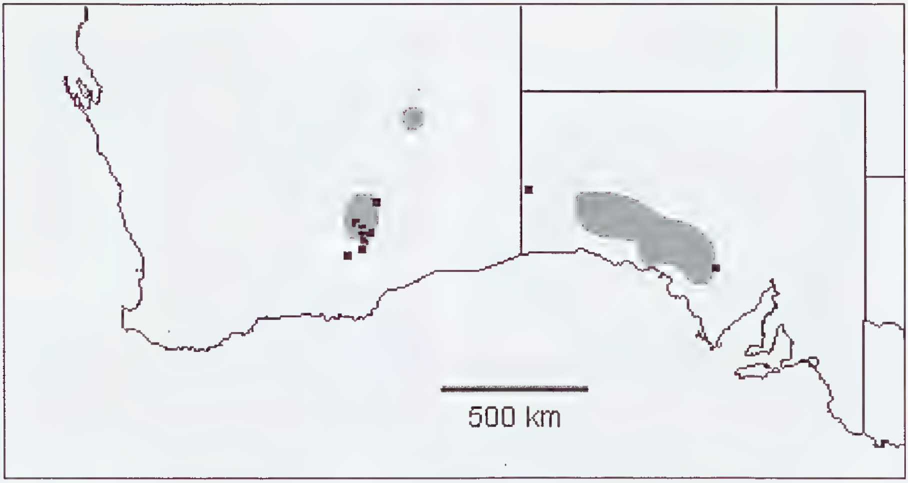

Figure 3. Distribution of *Diporiphora reginae* (squares). The approximate limits of the range of *D. linga* are indicated by the three grey shaded areas. WA portion modified from Western Australian Museum data.

Figure 4. Male *Diporiphora linga* from SE of Lake Ifould, South Australia (Photo: M. Hutchinson).

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COURTSHIP BEHAVIOUR IN A SOLITARY COLLETT'S SNAKE (*PSEUDECHIS COLLETTI*)

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INTRODUCTION

Courtship behaviour in elapid snakes is quite distinctive and identifiable. It is usually characterised by chin rubbing, jerking of the body in caudocephalic waves and dorsally mounting the potential mate (Carpenter, 1977). Under normal circumstances, a male displays these behaviours once a receptive female has been located. In this note we describe what appears to be an attempt by a male Collett's Snake (*Pseudechis colletti*) to court itself.

OBSERVATIONS

These observations were made on an adult male *P. colletti* on display in the Australian arid zone section of Reptile World at Taronga Zoo. The snake measured 1.52 m snout-vent length, 1.72 m total length and 1.4 kg mass. It was obtained as a juvenile in 1995 making it just over 13 years old at the time of these observations. The snake has always been kept singularly and is fed about 2-3 adult mice fortnightly.

Between September 2007 and April 2008, the temperature of the enclosure was maintained at 28°C during the day, dropping to ambient at night. From April 2008 until the observed behaviours, the daytime temperatures remained at 28°C whilst night temperatures were set at 24°C. Although the enclosure lighting is on between 0700 and 1700 hrs, opaque roofing above the exhibit allows the snake to experience the natural Sydney photoperiod. The enclosure is separated by glass and wire mesh from a trio of Inland Taipans (*Oxyuranus microlepidotus*) on one side and a trio of Black-headed Pythons (*Aspidites melanocephalus*) on the other. Both of these species are mixed-sex, and were observed copulating in the weeks coinciding with the observations below.

On 9 June 2008 at 0715 hrs, the Collett's Snake was observed laying in a circle with the head and neck overlapping the rear quarter of the body, making frequent jerking and rippling motions, similar to that displayed during male courtship behaviour. This coincided with rapid tongue flicking and chin rubbing on the posterior region of the back. As the snake moved forward it became more excited, increasing the rate of tongue flicking while attempting to keep up with the posterior portion of the body. This behaviour continued for five minutes on this occasion.

On 9 and 19 July 2008, between 0700 and 0800 hours, this behaviour was observed again, lasting for ten minutes and fifteen minutes respectively. On 20 July 2008, at 0730 hrs, the jerking body motions, chin pressing and rapid tongue flicking were again observed. On this occasion, the courtship behaviour continued for 70 minutes. This behaviour was again observed that day at 1030 and 1310 hrs, each time continuing for just under ten minutes from when it was first observed. This behaviour had not been seen in this snake prior to these observations.

DISCUSSION

The behaviour described for this *P. colletti* appears to be typical courtship behaviour for a male elapid snake (Carpenter, 1977). Prior to copulation, this species has been recorded to display jerking motions, chin rubbing and erratic tail movements (Charles, 1983; Eipper, 2000). The jerking motions and chin rubbing we observed were identical to male

courtship behaviours we have observed towards both female and male cage mates in other elapid snakes, including Inland Taipans (*O. microlepidotus*) and Red-bellied Black Snakes (*P. porphyriacus*).

It appears to us that this snake mistook the rear third of its own body for another, presumably female, snake. During the observations, any movement of the posterior third of the body instantly gained the interest of the snake, which immediately began chin rubbing and rapid tongue flicking. This suggests that the snake, in its excited desire to court and copulate, had confused the posterior portion of its own body for another snake.

Although we are unaware of this behaviour being previously described in an elapid species, it has been observed under different circumstances in the family Colubridae. Male Red-sided Garter Snakes (*Thamnophis sirtalis parietalis*) of Manitoba, Canada, demonstrate female mimicry by producing female-like skin pheromones (Shine *et al.*, 2000a). This causes male snakes to direct courtship behaviour to other males, in addition to females, distracting the attention of rival males away from the females (Shine *et al.*, 2000b). However, the male *T. s. parietalis* often become confused and attempt to court themselves (Shine, *pers. comm.*). Although the circumstances surrounding these observations are vastly different to the captive *P. colletti* in this note, it demonstrates the confusion created when a male snake has expressed an urgent desire to copulate. The influence of pheromones in our observation is not known, but it might be possible that the confusion was enhanced by pheromones released by the reproductive female snakes in the two adjoining exhibits.

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Thanks to Peter Harlow for making useful comments on a draft of this manuscript.

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AUTHOR OF FIRST AUSTRALIAN CHELONIAN BOOK DIES AT EIGHTY

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Although John Goode was neither a native born Australian nor a chelonian researcher by avocation, he was one of the pioneers of freshwater turtle research in Australia and New Guinea, writing a landmark book, "Freshwater Tortoises of Australia and New Guinea (in the family Chelidae)", Australia's first book devoted specifically to this group of reptiles, which laid the groundwork for many later publications in this area.

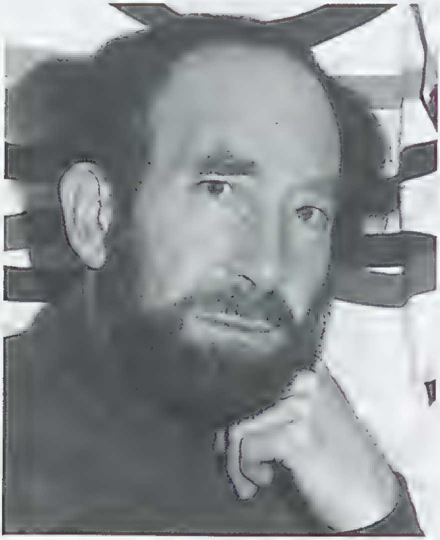
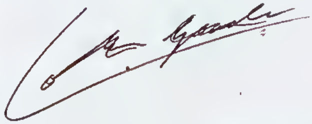


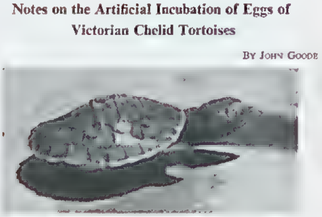
Figure 1. John in his study, mid 80s by his partner, Carol Willson.

Until John's treatise on Australia and New Guinea's tortoises was published in 1967, little was generally known on the subject. And there were very few researchers at this time. His book contributed greatly to the general knowledge of these turtles and stood alone for over a decade before the next books on Australian turtles were penned (Cann, 1978; Warren, 1979), the earlier of these authors crediting Goode with spurring his interest.

Figure 2. John's bookplate.

It also encouraged researchers to continue John's work and supplement the knowledge he had garnered. Although there are more up-to-date publications available on this subject, the book remains highly relevant and interesting through its pictures and text, and is essential reading for the serious student of Australian and New Guinean chelonians. Unfortunately, due to a relatively limited press run and current interest in the subject, it is now exceedingly difficult to obtain.

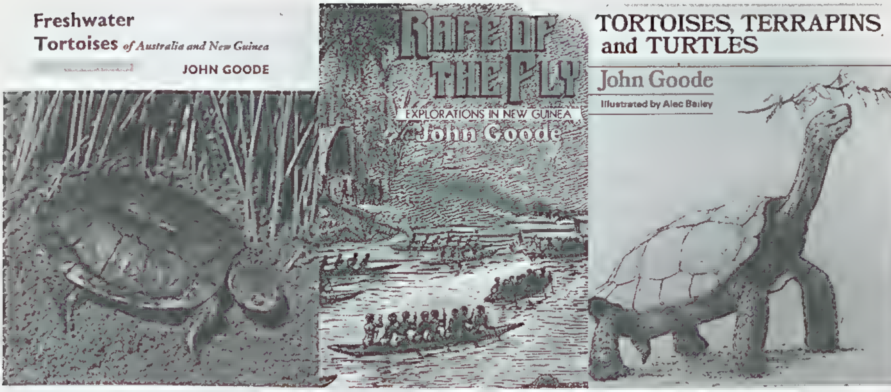




Notes on the Artificial Incubation of Eggs of Victorian Chelid Tortoises

By John Goode

Figures 3-4. John's signature and early article on turtle egg incubation



Figures 5-7. "Freshwater Tortoises of Australia and New Guinea (in the family Chelidae)", "Rape of the Fly", and "Tortoises, Terrapins, and Turtles".

John's interest on tortoises began when his son found one crossing the road and asked to keep it as a pet. John wanted to buy a book on the subject, but was surprised to find that none were available. This spurred him to begin research which spanned examination of historic literature, collection/examination of a wide range of specimens, and field trips to tortoise habitat. After a number of years, "Freshwater Tortoises of Australia and New Guinea (in the family Chelidae)" was published. The 154 page book begins with information on the strange tortoise found by Sir Joseph Banks and continues until modern times. It included new data, new keys, and even photos of embryos, something very unusual for its time, together with a chapter on captive care.

Among other research, John conducted extensive studies in the Murray River area on the nesting aspects of *Chelodina expansa* - including one nest dug up to reveal live young waiting in the chamber to escape some 627 days after the nest was first located, at the time a record period for freshwater turtles. (An even longer period, 664 days, was noted later by Cann (1981) based on information supplied by Jim Russell, John Goode's co-worker from the Murray River).

During the course of pursuing his chelonian studies, John's path led him to research the life and travels of Luigi Maria D'Albertis, an Italian explorer who, with the British-born Australian Lawrence Hargrave, extensively explored New Guinea's Fly River. John's research included not only travelling up the Fly River of western Papua New Guinea to get a feel of the atmosphere for his writing, but also consulting numerous unpublished primary sources in Australia, Italy and Britain. These efforts ultimately resulted in his groundbreaking 1977 book, "Rape of the Fly". We consider it one of the greatest natural history books ever written. Its 280 pages, maps, and 30 telling historical plates weave the story of the mid 1800s exploration of the Fly River area in Papua New Guinea and tell of the determination, rivalry, bitterness and achievement in the course of the exploration. This uncensored account of the lives and personalities of Luigi Maria D'Albertis and Lawrence Hargrave includes a large amount of previously unpublished material.

John spent seven years researching the work, but had difficulties in finding a publisher in Australia. D'Albertis' family in Italy wished to publish the book themselves; however as they would only publish it in Italian, he declined

the offer. The bibliography was so extensive that a grant from the federal government was obtained to assist in the publication, and it was eventually published by Thomas Nelson in West Melbourne, Victoria. Due to the large government grant, the publisher had made sufficient money to cover costs and profits. Unfortunately, in a large part due to the subsidy, it was removed from the shelves in a very short period. So John made little money from the extensive work he had carried out, and the book remains extremely scarce and greatly sought after by book collectors of exploration classics. It was during this period of his life that he met his partner, Carol Willson.

John Harvey Goode was born in London on October 15, 1927. He was educated in Britian and started off his working life as a draughtsman with a famous aircraft company. He later spent two years as a National Serviceman in the Royal Air Force where he dabbled in journalism, writing for the camp magazine. His journalistic life really began when he was discharged from service and began working for an art magazine in London.

He migrated to Australia in 1950, going straight to Queensland, where he was a jackaroo on a sheep property some miles from Quilpy. After this, he worked as a Mission Assistant on Thursday Island and at the Edward River Mission in Cape York. He briefly joined a merchant ship as a cook before attempting to earn his crust broadcasting on all manner of subjects on the ABC. During this time, he was also attempting to sell life insurance in pineapple country. He told Carol while the farmers couldn't afford the luxury of life insurance, they always sent him on his way with a bag of pineapples (which he hated).

Various jobs in the publishing industry kept him afloat in Melbourne before and after his tortoise research. He was interested in other wildlife, as the variety of subjects in his books, newspaper and magazine articles attest. He wrote many travel and food articles for a number of magazines and newspapers, also doing editorial work while working on his own material. Over twenty books were published on diverse subjects such as natural history, aeroplanes, cars, Australian history, children's books, and even food and cooking, sometimes under the *nom-de-plume* of "Harvey Johns". He was also a fellow of the Royal Geographical Society in London.

John retired to pursue horticultural interests just to keep busy and died on December 2, 2008, in Kingston, Tasmania, after a short illness. A Huon pine was planted in a local park in John's memory.

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NOTES TO CONTRIBUTORS

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The senior author will receive a PDF copy of their article.

Inland Bearded Dragon (*Pogona vitticeps*) from Wyperfeld National Park, Victoria (Photo: S. Watharow). See article on p. 21on the parasites of reptiles from the Victorian Mallee.

Bronzeback (*Ophidiocephalus taeniatus*) from Coglin Creek, Northern Territory (Photo: P. McDonald). See article on p.46 on the rediscovery of this species in the Northern Territory.